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VOLUME I
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BASIN F TO THE NORTH BOUNDARY AREA
ROCKY MOUNTAIN ARSENAL, DENVER, COLORADO

VOLUME I: GEOTECHNICAL DEFINITION

by
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WORKING DRAFT

Geotechnical Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

October 1979

Prepared for

Rocky Mountain Arsenal
Denver, Colorado
and
U. S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

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VOL I: THIS STUDY WAS MADE TO PROVIDE A DETAILED DEFINITION OF THE GEOLOGY AND GROUND WATER IN THE ALLUVIUM BETWEEN BASIN F AND THE NORTH BOUNDARY. THE STUDY AREA INCLUDES RMA SECTIONS 23, 24, 19, 26 & 25. THREE SPECIFIC QUESTIONS ARE ADDRESSED IN THIS STUDY: 1. WHAT ARE THE HYDROGEOLOGICAL CHARACTERISTICS OF THE ALLUVIAL AQUIFER FROM BASIN F TO THE NORTH BOUNDARY? 2. WHAT ARE THE LOCATIONS, MOVEMENTS & CONCENTRATIONS OF VARIOUS POLLUTANTS IN THE ALLUVIAL AQUIFER? 3. ARE FIRST CREEK, THE SEWAGE LAGOON, SANITARY SEWER LINE AND DEEP WASTE INJECTION DISPOSAL WELL POLLUTION SOURCES CONCURRENT WITH THIS STUDY, A CONTAMINANT IDENTIFICATION & MIGRATION STUDY WAS PERFORMED. THE RESULTS OF THAT STUDY ARE SUBMITTED SEPARATELY IN "BASIN F TO THE NORTH BOUNDARY, VOL II: GROUNDWATER ANALYSIS II VOL II PRESENTS ANSWERS TO QUESTIONS 2 AND 3 ABOVE. (SEE # 81352M045).

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PREFACE

This investigation was conducted during the period 16 October 1978 to 30 September 1979 by personnel of the Geotechnical Laboratory (GL) of the U. S. Army Engineer Waterways Experiment Station (WES) under the Contamination Control Program of the Rocky Mountain Arsenal (RMA), Commerce City, CO. Funding for this study was authorized by IAO No. 79-20 (change 1) dated 3 October 1979 and IAO No. RM 67-79 (changes 1-3) dated 27 March 1979.

This report was prepared by MAJ Robert A. Zebell of the Engineering Geology Applications Group (EGAG) of the Engineering Geology and Rock Mechanics Division (EGRMD) of the GL with the advice, consultation, and recommendations of personnel in the Environmental Engineering Division, Environmental Laboratory. Technical assistance for permeability testing analysis, and evaluation were provided by Mr. J. B. Warriner of the Rock Mechanics Application Group, EGRMD of the GL. The report was prepared under the direct supervision of Mr. J. H. Shamburger, Chief, EGAG, and under the general supervision of Dr. D. C. Banks, Chief, EGRMD, and Mr. J. P. Sale, Chief, GL.

Special acknowledgement is extended to the following individuals for their assistance during the study: Messrs. Ed Berry, Irvin Glassman, Don Cook, Brian Anderson, Greg Ward, and Carl Loven of RMA; and Messrs. Andrew Anderson, James Zarzycki, and Don Campbell, U. S. Army Toxic and Hazardous Materials Agency, Edgewood Arsenal, MD.

Commanders and Directors of WES during the preparation of this report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) AND METRIC (SI) TO U. S. CUSTOMARY UNITS OF MEASUREMENT

Units of measurement used in this report can be converted as follows:

Multiply	By	To Obtain
	U. S. Customary to Metric (SI)	
inches	2.54	centimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
square feet	0.09290304	square metres
acres	4046.856	square metres
feet per day	0.3048	metres per day
gallons per year	0.003785412	cubic metres per year
Fahrenheit degrees	0.555	Celsius degrees or Kelvins*
	Metric (SI) to U. S. Customary	
millimetres	0.03937007	inches
centimetres per second	0.3937007	inches per second

* To obtain Celcius (C) readings from Fahrenheit (F) readings, use the following formula: $C = 0.555(F - 32)$. To obtain Kelvin (K) readings, use: $K = 0.55(F + 459.67)$.

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BASIN F TO THE NORTH BOUNDARY AREA
ROCKY MOUNTAIN ARSENAL, DENVER, COLORADO

VOLUME I: GEOTECHNICAL DEFINITION

PART I: INTRODUCTION

Background

1. Basin F (also called Reservoir F) is one of a group of basins at Rocky Mountain Arsenal (RMA) where liquid wastes from the manufacture of munitions and chemicals were stored over a period of years. Basin F is believed to be a significant contributor of pollutants to groundwater in the area.

2. The discovery of pollutants in groundwater, believed to be related to RMA industrial activities, north of RMA resulted in legal actions which require that groundwater exiting RMA be intercepted and satisfactorily treated prior to its leaving RMA.

3. Studies were made of the pollution problem and a pilot containment system was constructed to treat pollutants leaving the RMA at the north boundary. The system was found to be adequate for the area being served by this system and will be expanded upon completion of studies which are to determine the scope of the pollution problem at the north boundary.

Purpose and Scope

4. This study was made to provide a detailed definition of the geology and groundwater in the alluvium between Basin F and the north boundary. The study area includes RMA sections 23 and 24; section 19 adjacent to and west of the First Creek area; section 26 north of Basin F; and the extreme northwest corner of section 25. Three specific questions are addressed in this study:

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a. What are the hydrogeological characteristics of the alluvial aquifer from Basin F to the north boundary?

b. What are the locations, movements, and concentrations of various pollutants in the alluvial aquifer?

c. Are First Creek, the sewage lagoon, sanitary sewer line, and deep waste injection disposal well pollution sources?

5. Previous studies have indicated the presence of a shallow waterbearing strata, referred to as the alluvial aquifer, which is underlain primarily by weathered clays and soft shales and sands of the Denver formation (frequently referred to as "bedrock"). This study was restricted to the alluvial aquifer and a separate study is being made of the Denver formation aquifers. However, during the course of this study, some Denver formation sand units were found to be in direct contact with the alluvial aquifer and are acting in conjunction with the alluvial aquifer as a unit. In such cases, sands in the Denver formation were treated as part of the alluvial aquifer.

6. Concurrent with this study, a contaminant identification and migration study was performed by the Environmental Laboratory (EL) of the Waterways Experiment Station (WES). The results of that study are being submitted separately in a report entitled "Basin F to the North Boundary, Volume II: Groundwater Quality Analysis."

7. Volume II presents answers to items b and c in paragraph 4 above.

Previous Studies

8. The alluvial aquifer underlying RMA and surrounding areas has been investigated several times since 1953. Successive studies elaborated on earlier studies and became progressively more detailed with respect to RMA. None of the studies dealt exclusively with the study area of this report. A brief discussion of the findings of each study pertinent to the Basin F to the North Boundary study is presented below.

9. Pleistocene and Recent deposits in the Rocky Mountain region and the Denver area are described in general U. S. Geological Survey (USGS) bulletins as being of pre-Wisconsin, Wisconsin, and Recent age. The pre-Wisconsin deposits contain alluvial gravels in the valleys and at higher elevations. The Wisconsin age alluvium in the valleys represent glacial outwash from the Front Range. The eolian deposits of Wisconsin age were derived from valleys and are primarily found at higher elevations on the leeward (eastern) side of the valleys. Recent deposits are generally alluvium and also include reworked eolian sands. The Denver formation underlies the Pleistocene and Recent deposits and is composed of clays, shales, and siltstones with some lenticular sands and thin seams of lignite. The Denver formation surface is deeply weathered and generally conforms with the present topography; however, the Denver surface is more irregular and has greater relief. A typical section of Pleistocene and Recent deposits around RMA shows basal gravels and sands overlain by finer sediments (clays, silts, and fine sands).

10. Later geological studies, which were oriented on RMA, have stratigraphic cross sections passing through the study area and identify the alluvial aquifer to be underlain by the Dawson formation (equivalent to the Denver and Arapaho formations). The cross sections identify the deposits immediately overlying the Dawson to be the Verdos alluvium (Kansan). The Verdos is composed of boulders, cobbles, pebbles, and sands derived from granites and pegmatites with some Cretaceous shale boulders. The Verdos is found in the valleys and capping the hills and reaches thicknesses up to 100 ft. Above the Verdos is eolian sand of Recent and Wisconsin age as well as Recent alluvial deposits. Sands up to 40 ft thick have accumulated from separate deposition periods. Along First Creek and at other isolated locations at RMA, the Piney Creek (Recent) alluvium is found which consists of up to 8 ft of brown to dark gray silts, clays, and sands.

11. Several studies contain water table, top of bedrock, and saturated thickness (isopach) maps. While general in nature, these maps provide historical data and contain data points specific to this study

area. The top of bedrock maps show a main channel running northeast from Basin F and a second channel following the trace of First Creek. Several small separate channels are shown along the north boundary and one other channel is a tributary to the channel under First Creek. Two bedrock high areas are found near the eastern and western limits of the study area. Saturated thickness maps show the greatest saturated thicknesses in bedrock channels. The water table maps show groundwater moving in a northerly direction or in a northeasterly direction from Basin F and in a northwesterly direction in the vicinity of First Creek. The flow patterns converge near the center of the study area and the resultant flow is to the north. Also shown are dry areas in the vicinity of the bedrock highs near the eastern and western limits of the study area and one area northeast of Basin F. The flow of pollutants depicted in earlier studies is from Basin F to the north and exiting RMA along the north boundary.

PART II: SUBSURFACE GEOLOGIC CONDITIONS

Field Exploration

12. To determine sources and quantity of the groundwater as well as flow directions, borings were needed to intercept groundwater before and after it passed a potential source of contamination. Previous boring locations and logs were reviewed and a boring and sampling program was designed to fill data gaps in sections 23 and 26 and to evaluate potential pollution migration in sections 19, 24, 25, and 26. Seventy-five new borings (Nos. 900–974) and borings 378–380, 382, 385, and 533 were located to supplement the existing boring data. (Note: Additional 900 series borings were drilled for the Denver formation aquifer study and some were used in this study.) Split-spoon samples were obtained at 5-ft intervals and at stratum changes, where possible, from each boring. Samples were field classified on site by several inspectors. Because each inspector described the soil samples differently, all samples were reclassified and stratigraphic breaks were revised on the boring logs. Additionally, where available, selected samples of previous borings were reclassified. Because some borings were drilled as far back as 1957, many samples were not available for examination. Laboratory classification was performed on selected soil samples and the grain size curves are presented in Appendix A.

13. Piezometers were installed at all new boring locations for water level measurements, water sampling, and permeability tests. The piezometer installation consisted of placing a 2-in.-diam PVC pipe with a slotted PVC screen in the water-bearing layer. A 5-ft-long capped PVC trap was connected below the screen and pea gravel was placed around the entire length of the screen. The piezometers were flushed with water (except for those installed in areas where the alluvium appeared to be dry) immediately after installation. Later the piezometers were developed by using high pressure air to blow water from the piezometer trap until the water was clear.

Data Analysis and Presentation

14. All available logs and water depth readings from piezometers were used to construct cross sections and water table, base of the alluvial aquifer, and saturated thickness maps. The boring, piezometer, and cross-section locations are shown in Figure 1. The cross sections are shown in Plates 1 through 5. On each of the five plates, two types of data are presented—one cross section contains general soil types and water levels and below it another cross section presents the stratigraphy. The cross sections are discussed individually below. The other maps are discussed in a subsequent part of this report. Prominent subsurface highs and channels (high and low elevation) on the top of the Denver formation are designated on the plates and Figure 5 by a letter (A) and a number (1), respectively. These features are designated the same on all the cross sections.

Cross section A-A'

15. Section A-A' (Plate 1) is located along the southern boundary of sections 23 and 24 and terminates near the western end of section 19. The section is roughly perpendicular to the northerly flow of groundwater in the alluvial aquifer. In the western half of the cross section, the base of the alluvium is underlain by clays or clay shales of the Denver formation. Two alluvial channels are recognizable in the western part of the cross section. The wide channel is designated as channel 1 and the other channel is near the western limit of the cross section and is relatively narrow. These channels are separated by a clay shale high which is the southern extension of Denver High "A" (see Figure 5). The maximum elevation difference between the channels and the high is about 10 ft. The top of the Denver formation is weathered shale except for an area at the center of the large channel which is composed of silty sands and sandy clays. The Denver is covered with 20 to 25 ft of Verdos alluvial gravels and sands with occasional lenses of silts and clays. The gravels and sands are well graded with cobbles included. Overlying

the Verdos is 10 to 20 ft of fine sands, silts, and clays. These soils are eolian sands and alluvium transported from a higher elevation. The eastern half of the cross section (RMA section 24 and the western end of section 19) is significantly different from the western half. In this part of the cross section the top of the Denver formation is composed of silty fine to medium sand with occasional clay lenses. These sands are in direct contact with the overlying alluvial sands and gravels making both of these units act as a single hydrogeologic unit. Underlying the Denver sand unit, the weathered Denver shale rises abruptly into a scarp and decreases in elevation to the east. This scarp is identified as Denver High "B" in Plate 1 and Figure 5. Several small channels occur east of the Denver High "B" in the Denver shales. The Verdos sands and gravels thin rapidly eastward from channel 1 over the Denver High "B" and contain some reworked Denver sands. Gravel sizes are predominantly fine and the gravels are intermittent. Fine sands, silts, and clays overlay the Verdos and are similar to those in the western half of the cross section. The Piney Creek alluvium is present in the area of First Creek and consists of clays, silts, and sands. East of the Denver High "B", the Denver sands are from 0 to 25 ft thick; the Verdos sands and gravels are from 5 to 20 ft thick; and the fine sands, silts, and clays are from 5 to 15 ft thick.*

Cross section B-B'

16. Section B-B' (see Plate 2) is roughly perpendicular to the northward flow of alluvial groundwater. The base of the alluvial aquifer is weathered Denver shale. A prominent Denver high is near the center of section 23 (designated as "A" on the cross section). West of High "A" the Denver formation decreases in elevation. East of High "A" three successively lower and deeper channels occur in the Denver. The middle channel is designated as "1" on Plate 2. East of the third and deepest channel is another Denver high, designated as "B" on the cross section. The Denver High "B" is 24 ft above the bottom of the channel. East of

* Note: The Piney Creek alluvium and other Recent deposits are not differentiated on the cross sections. The Recent deposits are generally designated as clays, silts, and sands and the Verdos alluvium is designated as sands and gravels.

the Denver High "B" is one relatively shallow channel and two larger channels designated as "2" and "3" with Denver High "C" between the channels. The Verdos sands and gravels northwest of Denver High "A" are thin and intermittent and are 0 to 4 ft thick. Between High "A" and High "B" the sands and gravels are 10 to 40 ft thick and are thickest in the channels. East of the Denver High "B" the Verdos sands and gravels are from 5 to 25 ft thick and, again, are thickest in the channels. The gravels east of the High "B", as in section A-A', are fine grained whereas those west of High "B" are coarse grained and include cobbles. The Denver sands found to the south in section A-A' have pinched out before reaching this cross section. Overlying the sands and gravels are clays, silts, and fine sands in thicknesses from 5 to 25 ft. As in cross section A-A', these soils consist of eolian sands and alluvium transported from higher elevations, except at the eastern limit of the section where Piney Creek alluvial sands, silts, and clays occur in the vicinity of First Creek.

Cross section C-C'

17. Section C-C' (Plate 3) is just south of, and parallel to, the north boundary and crosses sections 23 and 24; the section is perpendicular to the northerly flow of groundwater in the alluvial aquifer. This section identifies the base of the alluvial aquifer as weathered Denver shale except for two areas which are identified later. Denver High "A" occurs near the center of the western half of the cross section and is the northerly extension of the Denver High "A" in cross section B-B'. West of the Denver High "A" the Denver surface decreases in elevation and contains two small channels. Between these two channels, the Denver formation consists of silt and clayey sand. East of the High "A" is one small, narrow channel and one shallow, wide channel followed by a wide, flat surface extending across the boundary of sections 23 and 24. The center of section 24 has one large channel (identified in Plate 3 as channel 1) with two smaller channels to its west. The Denver formation between the channels consists of silty and clayey sands. East of channel 1 the Denver surface rises rapidly and forms the Denver High

"D". The Verdos sands and gravels, west of the Denver High "A", are from 0 to 10 ft thick and thicken to the west. East of the Denver High "A" the Verdos alluvium reappears and ranges in thickness from 5 to 25 ft with thickest deposits occurring in the channels. With the exception of the Denver High "A", coarse to fine gravels appear intermittently throughout the alluvium. Overlying the Verdos sands and gravels are clays, fine sands, and silts ranging in thickness from 5 to 20 ft. These sediments are in direct contact with the Denver formation where the Verdos is absent on the High "A". These soils consist of eolian sands and alluvium transported from higher elevations, except for the areas in and adjacent to the First Creek valley (center of section 24 in Plate 3) and the small valley west of the section 23 and 24 boundary where Piney Creek alluvial clays, silts, and sands occur.

Cross section D-D'

18. Section D-D' (Plate 4) starts at the northwest corner of Basin F and runs northeast to the north boundary near the intersection of sections 23 and 24. This section is roughly parallel to the north-northeasterly flow of alluvial groundwater. Along this cross section the base of the alluvial aquifer is weathered Denver shale except for a small area northeast of the section 23 and 26 boundary where the Denver is composed of sands and clayey sands. The Denver surface has little relief except at the center of the section where several tributaries to channel 1 are crossed. The Verdos gravels and sands are up to 35 ft thick in the southwestern half of the section and thin to 10 ft in the northeast. Above the sands and gravels are clays, silts, and fine-grained sands with thicknesses along the section of 15 ft in the southwest, up to 30 ft in the center and between 5 and 10 ft in the northeast. Some of the sediments in and adjacent to the surface drainage channel in the northeastern part of the section are probably Piney Creek alluvial clays, silts, and sands.

Cross section E-E'

19. Section E-E' (Plate 5) starts near the southeastern corner of section 24 and runs northwesterly to a point near the northwest corner

of section 24 and is roughly parallel with the north-northwesterly flow of alluvial groundwater. The base of the alluvial aquifer is weathered Denver shale except in the southeastern one-third of this section, where a sand unit of the Denver formation lies between the alluvium and the weathered shale. The sand unit is wedge-shaped and thins to the northwest from 25 ft where it pinches out on the Denver High "B" near the center of the section. A second Denver sand occurs at the northwestern end of the section near the northern boundary. This Denver clayey sand lies between weathered Denver shales and the alluvium and is approximately 4 ft thick. Both Denver sands are saturated and are acting in conjunction with the alluvial aquifer materials. Two channels occur in the northwestern half of the section, the largest is identified as channel 1. The other channel is just west of channel 1. Southeast of channel 1 the section crosses the northeasterly trending Denver High "B". Southeast of this high the cross section enters channel 2. Above the Denver sands and the weathered Denver shales are the Verdos sands and gravels which are 10 to 25 ft thick in the center and southeastern parts of the section and thin to 10 to 15 ft in the northwest except for channel 1 in the northwest where the sands and gravels are 25 ft thick. Above the Verdos are clays, silts, and fine sands ranging in thicknesses from 5 to 10 ft. At the northwest end of the section, Piney Creek alluvium consisting of clays, silts, and fine sands occur.

PART III: GROUNDWATER DEFINITION

20. Existing hydrogeological data were reviewed prior to developing the investigation program for the Basin F to the North Boundary study area. Historical water level data were reviewed to determine possible long-term trends in the alluvial aquifer. New borings and piezometers were located to fill gaps in the existing boring and piezometer array. Data from the logs and piezometers were used to determine water table elevations, base of alluvial aquifer, groundwater flow patterns and groundwater quantity. Each of these items are discussed in subsequent paragraphs.

Water Table

21. Water table measurements were taken in the study area in October-November 1978 and, upon completion of the installation of new piezometers, Arsenal-wide measurements were taken in March-April 1979 and in May-June 1979. The 1978 water table data did not cover the southeastern part of section 24 and the western part of section 19 around First Creek because these areas were void of piezometers. After installation of the new piezometers, during February and March 1979, the area was included in the water table measurement program.

22. The three sets of water table measurements were reviewed. Water table fluctuations during the relatively short period of this study were found to be small, therefore, only one water table map, for May-June 1979, was constructed (Figure 2). Selected measurements taken between 1976-1978, where available, are presented in Table 1.

23. The water table contours show three spacing and direction patterns. The first pattern occurs in the western part of the study area (section 23) and is characterized by widely spaced contour lines (low gradient) that trend to the northeast. The second pattern occurs in the eastern part of the study area (sections 24 and 19). This pattern is characterized by closely spaced contours trending in a northwest

direction. About 1200 ft south of the north boundary, the first and second patterns converge to form closely spaced contour patterns that trend in a northerly direction. The occurrence of Denver shale highs have a definite influence in the water table contour patterns. For example, the dry area indicated on Figure 2 are underlain by Denver shales at higher elevations than the water table. Additional discussions of the Denver shales will be presented under the section, "Base of the Alluvial Aquifer."

Water Table Fluctuations

24. An analysis was made of the 1979 water table map and previous water table maps to determine what changes have occurred. Previous data used for this analysis were from the U. S. Geological Survey (USGS) report (1957 data) and the U. S. Army Engineer District-Omaha report (1959-60 data). This analysis identified significant water table changes in the study area (see Figures 3 and 4). The water table variations between 1959 and 1979 are presented in cross sections in Plates 1, 2, 4, and 5.

25. Water table data in the USGS and Omaha reports show the most significant changes in the vicinity of Basin F. In 1957, the water table elevation immediately north of Basin F was 5160 ft, in 1959-60 it was 5150 ft, and in 1979 is 5147 ft. The 13-ft decline between 1957-1979 is the largest in the study area. Approximately 1/2 mile north of Basin F, in the center of section 23, the water table elevation was 5148 ft in 1957, in 1959-60 it was approximately 5146 ft, and it is now 5145 ft. At the northern boundary of section 23, the water table data for 1959-60 and the present indicate that the water table is now 2-4 ft higher. The data control in the 1957 report at the north boundary is limited so a comparison is not possible using 1957 data. The net effect of these changes is a reduction in the south to north water table gradient and the saturated thicknesses in the vicinity of Basin F. It should be noted that Basin F (an asphalt lined basin) was used for disposal of industrial waste since 1957 except for the period from 1962 to 1966 and this was probably a significant factor in the declining water table

elevations at Basin F. This lining initially inhibited recharge to the aquifer; however, indications are that the lining degraded which resulted in fluid from the basin entering the alluvial aquifer.

26. The water table elevations in section 24, from 1957 until the present, have shown little or no change except in the southwestern area of the section where water levels have declined 5-10 ft. At the northern boundary of section 24, water table levels were estimated in the 1957 USGS report and were not used for comparison. The Omaha District report only shows minor variations with respect to current data at the northern boundary. The lack of water table changes in the eastern part of section 24 probably reflects the influence of First Creek. The drop in the water table in southwestern section 24 appears to be related to the water table decline in the vicinity of Basin F.

Base of Alluvial Aquifer

27. The base of the alluvial aquifer is presented in Figure 5. The map generally depicts the weathered shale surface of the Denver formation which underlies the alluvium but includes the Denver formation sands where they are in direct contact with the alluvium. The general slope of the base of the alluvial aquifer is to the north-northeast north of Basin F and north-northwest in section 24. These slopes dictate the flow of alluvial groundwater. The map shows Denver High "A" just west of the center of section 23 with a northeast-southwest axis and Denver High "D" in the northeast corner of section 24 which trends northwest-southeast. The smaller Denver High "B" runs from the southeast corner of section 24 to the northeast. This ridge is dissected by the two southeast-northwest channels ("2" and "3") in the eastern half of section 24. Section 23 has one main channel ("1") starting north of Basin F which runs northeast into section 24. Channel 1 has several tributary channels entering from the west and south. Channel 1 combines with channels 2 and 3 in section 24 near the north boundary. Five other small north trending channels cross the north boundary. Two of these channels are in the western half of section 24, two are in the eastern

half of section 23, and one is near the western boundary of section 23. One other channel starts at the northwest corner of Basin F and exits the study area to the northwest.

Saturated Thickness of Aquifer

28. Figure 6 is an isopach map showing the saturated thickness of the alluvial aquifer which includes Denver sands that are in contact with the alluvium. The map reflects saturated thicknesses based on the differences between the base of the alluvial aquifer surface and piezometer surface. Figure 6 presents all saturated sediments which includes fine-grained materials of relatively low permeability. As expected, areas of greatest saturated thicknesses follow channels and the areas of least saturated thicknesses generally coincide with the Denver formation highs.

Groundwater Flow Pattern

29. The present (1979) groundwater flow directions are perpendicular to the contour lines on the water table map. As previously discussed, in the eastern part of the study area, the flow direction is to the northwest; in the western part of the study area, the flow is to the northeast. These flow directions merge about 1200 ft south of the north boundary and the flow direction changes to the north. The flow paths are also similar to the channels identified in the base of the alluvial aquifer map. Flow directions have varied from 1957 to present because of the decrease in water table elevations (see Figures 2, 3, and 4).

30. In 1957 groundwater flowed northward in sections 23 and 24. In 1959-60 the flow direction in section 23 was to the north-northeast and in section 24 the flow was primarily to the north. At the present time, the groundwater flow is to the northeast in section 23 and to the northwest in section 24. The only exception in sections 23 and 24 is at and near the north boundary where the flow has been primarily northward during the period 1957 to 1979. The net effects of these changes are:

a. Groundwater flow from Basin F to the north boundary, as a percentage of the total flow across the north boundary, has decreased and has changed from a northerly to a northeasterly direction.

b. The flow of groundwater in section 24 has increased as a percentage of the total flow across the northern boundary and has changed from a northerly to a northwesterly flow direction.

c. The flow direction of groundwater near the north boundary has remained northerly.

31. Present groundwater flow pattern deflections in the vicinity of the pilot plant indicate that groundwater may be moving around the eastern and western limits of the plant. However, when the current contour pattern on the western end of the plant is compared with the 1959-60 water table map, a similar pattern existed nearly 20 years prior to the plant's construction. It appears that the construction of the pilot plant has not influenced groundwater flow west of the plant. When a similar comparison is made on the eastern end of the plant, there appears to be a deflection pattern developing which is not on the 1959-60 map. Two factors are believed to have created the deflection pattern: First, water recharge rates have not been aligned with dewatering rates and, second, water recharging rates have been terminated in all wells except for those at the extreme eastern end of the plant from the end of January 1979 through mid-March 1979 and the last half of May 1979. These factors can have significant impacts on groundwater levels and flow patterns and complicate an evaluation of the groundwater flow pattern.

32. To minimize changes in the water table system, dewatering well rates should match recharging well rates for wells north and south of the bentonite barrier in the pilot plant system. Since the initiation of plant operations (July 1978 through August 1979), the eastern half of the plant has had a recharge deficit (total dewatering volume versus total recharging volume) of approximately 6.2 million gal or nearly

30 percent of the dewatering total. On the other hand, the western half of the plant has had a recharge surplus during the same period (Table 2).

Groundwater Quantity

33. Field pump tests and rising and falling head (slug) tests were performed in the study area to determine the coefficients of permeability of the alluvial aquifer. Tables 3 and 4 summarize the field pumping and slug tests, respectively.

Field Pump Tests

34. Five pump tests were performed in 1978 by WES. Three tests were performed north and northeast of Basin F in section 23 and two tests were performed in section 24. One test was southwest of the sewage lagoon and the other test was north of the sewage lagoon near the north boundary. Wells 345, 368, 529, 548, and 549 were used for the tests. Observation wells were installed on lines originating at the test well extending to 1000 ft away from the test well. During the pump tests water level changes in the observation wells were measured for drawdown and recovery and coefficients of permeability were computated using the drawdown and recovery rates. Coefficients of permeability computed from test wells 345, 368, and 529 ranged from 2400 to 12,000 gpd/ft^2 and the coefficients of permeability on the observation well lines ranged from 3400 to 8200 gpd/ft^2. These wells are in, or adjacent to, a subsurface channel "1" which runs northeast from north of Basin F towards the north boundary (see Figure 5). Well 548, located astride a small ridgelike area, had a coefficient of permeability of 1100 gpd/ft^2; coefficients of permeability on the observation well lines were from 1300 to 2000 gpd/ft^2. Well 549, located adjacent to Denver High "B" and in an area of rapid groundwater gradient changes, has a coefficient of permeability of 430 gpd/ft^2. The observation well lines reflected rapid changes in the coefficient of permeability when measured over a short distance (0-50 ft; 250 gpd/ft^2) as compared with a long distance (50-1000 ft, 1100 gpd/ft^2). These differences could be caused by the influence of the main channel at their extremities.

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$$k = \ln\left(\frac{R_e}{r_w}\right) \frac{1}{2L} \frac{r_w^2}{t_1} \qquad (1)$$

where

k = coefficient of permeability ($L^3/T/L^2$)

R_e = radius of influence of the test (L)

r_w = radius of well (equal to radius of screen in all of the RMA tests (L)

L = screen length (L)

t_1 = time value on data plot coinciding with t = 1.0 sec (T)

For fully penetrating wells:

$$\ln\left(\frac{R_e}{r_w}\right) = \left(\frac{1.1}{\ln\left(\frac{H}{r_w}\right)} + \frac{C}{L/r_w}\right)^{-1} \qquad (2)$$

where

H = height of stable water level above bottom of screen (L)

C = value obtained from plotted results of electrical analog tests for a specific value of L/r_w (dimensionless) (Plate B2)

For partially penetrating wells:

$$\ln\left(\frac{R_e}{r_w}\right) = \left(\frac{1.1}{\ln\left(H/r_w\right)} + \frac{A + B\ln\left(\frac{D - H}{r_w}\right)}{L/r_w}\right)^{-1} \qquad (3)$$

where

D = height of stable water level above bottom of aquifer (L)

A = value obtained from plotted results of electrical analog tests for a specific value of L/r_w (dimensionless) (Plate B2)

B = value obtained from plotted results of electrical analog tests for a specific value of L/r_w (dimensionless) (Plate B2)

If the groundwater response in the aquifer during the short period of the tests and for the small volumes involved indicates continued storage conditions, then the coefficient of storage can be calculated from:

$$S = \frac{r_c^2}{r_s^2}\alpha \qquad (4)$$

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where

S = coefficient of storage of the aquifer (dimensionless)

r_c = radius of casing in interval of water level fluctuation (L)

r_s = radius of screen (L)

α = value obtained from type curve (dimensionless)

Transmissibility is calculated from:

$$T = \frac{r_w^2}{t_1} \tag{5}$$

where r_w and t were previously defined and coefficient of permeability is calculated from:

$$k = \frac{T}{L} \tag{6}$$

where T and L were previously defined.

39. The wells used for slug tests were 8 in. in diameter and were backfilled by pea gravel subsequent to placement of the piezometers and prior to sealing with cuttings. The piezometer risers and screens were 1.0 in. inside radius. Therefore, in the analyses with Equations 1, 2, 3, 4, and 5 it was assumed that $r_c = r_s = r_w = 1.0$ in. = 2.54 cm. An argument may be made for using 8 in., the nominal boring radius for r_w, the radius of the well. There was poor control of the actual bored radii due to the variability in competency of the strata penetrated. There was, despite greater than normal precaution, uncertainty in the lengths of the gravel packing around the screens. Also, regardless of the actual as-placed top elevations of the gravel packings, they were usually below the elevations of the surrounding water tables and were usually also below the lowest elevations achieved in the bailing operation that initiated the slug tests. Therefore, the assumption was made that the gravel packs remained saturated and were more permeable than the natural aquifers. Consequently, the above stated quality of radii was used in the analyses.

35. The rising and falling head (slug) tests were conducted mainly in areas where no pump tests had been performed. Some testing was done west of the existing pilot plant and at other locations.

36. The slug test consists of placing a calibrated pressure transducer in a well to measure the water level in that well, removing (or injecting) a volume of water from (into) the well to change the water level in as nearly instantaneous a manner as possible and recording the recovery of the water level to its original value with the passage of time. The continuous record of water level versus time is then plotted as the ratio of measured head of water in the well to the initial head of water upon withdrawal (or injection) at time zero (called the "recovery ratio" or H/H_o) versus the logarithm of elapsed time in seconds. The curvilinear graph is then matched to a previously calculated family of theoretical curves that includes the variables of coefficient of storage, transmissibility, permeability, and confining conditions. The curves generated from the slug tests are presented in Appendix B. Derivations, tabulations, and graphical representations of those curves are presented by Bouwer and Rice, (1976), Cooper et al. (1967), and Papadopulos et al. (1973).

37. Upon successfully matching the field data plot to one of the theoretical type curves, the nature of aquifer confinement is identified by the shape of the curve and the value of " " for the matched curve. Also the value of time is noted on the data plot which coincides with the time of 1.0 sec on the theoretical type curve.

38. If the groundwater response in the aquifer during the short period of the test and for the small volumes involved indicates unconfined conditions, then the proper type curve can be matched so that a value of the coefficient of permeability can be obtained from the equation:

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The screen lengths were used for the values of L in equations 1, 2, 3, and 6 were determined in the following way. A 4-ft screen section was measured and found to consist of 85 percent of its total length comprising the slotted portion and the remainder of the total length being solid end sections and couplings. Therefore, the screen lengths of each piezometer were multiplied by 0.85 to obtain the value used for L in that particular calculation. In a few instances, the screen sections extended into the lower Denver clay shale or aquiclude. In those instances the elevation differences between the tops of the screens and the aquiclude were used as the nominal screen lengths to which the 0.85 adjustment was applied. All the above assumptions and considerations have been applied to all previous slug test analyses from RMA piezometers as described. This procedure makes all the results of RMA slug test analyses internally and directly comparable, at least as far as the design, construction, and final configuration of the piezometers are comparable.

40. The bailer used at RMA for the slug tests had a nominal 2.0-liter capacity. This volume of extracted water caused an initial water level change of approximately 3.2 ft in the casing. Variations in the degree of filling the bailer coupled with water level recovery during the 1-2 sec allowed for surging and dribble-back resulted in the initial water level being up to 0.5 ft less than the maximum possible. The pressure transducer, together with the resolution of the continuous oscillographic recorder, provided a measured precision of ±0.01 ft head of water. Depending upon the time scale used for a particular test the precision in time measurements was either ±0.01 or ±0.10 sec with the latter most commonly used. The transducer and recorder were used for water level measurements from the initiation of a test to either its completion (judged to be 95 percent recovery) or 3000 sec elapsed time, whichever came first. If the test had not reached completion in 3000 sec then the M-scope water level detector was used at periodic intervals thereafter to completion. Each initial M-scope reading was made while the transducer data was still being recorded to provide a consistent

data initial base. It was found that the M-scope data was reliable to about ±0.05 ft of water level and the time reliability good to about ±1 min.

Alluvial Aquifer Flow Rates

41. Flow rates in the alluvial aquifer were calculated across three cross sections, A-A', B-B', and C-C' (see Figure 1). Each of the cross sections were divided into zones (see Figure 7) for flow calculations for three reasons: (a) permeability values vary from one zone to another; (b) contaminants were found to be concentrated in several well-defined areas on each cross section line and these areas correspond to many of the zones selected based on permeability data; and (c) water table gradients vary significantly between many of the zones and these gradients usually reflect different geologic conditions.

42. The gradient data were extracted from the 1979 water table map. Saturated areas were taken from the cross sections. The saturated areas were adjusted by deducting areas of low permeability, such as clays, silts, and sandy clays, from the totals (Table 5). Permeabilities used for computations were based on pump test results and/or slug tests.

43. The alluvial aquifer flow rates across the cross section lines show successive increases towards the north (Table 6). The average flows across the cross sections are: A-A', 185,300 gpd; B-B', 370,200 gpd, and C-C', 884,100 gpd. The progressive increases in flows towards the north are probably the result of input from rainfall, the First Creek, the sewage lagoon, and flows into the study area from the east. It is possible that some input could be coming from the Denver formation, however, no attempt was made to measure this possible input. A detailed discussion of the flows, by cross section, is below.

a. Cross section A-A' has two distinct permeability areas. The first area, Zone 1, has one narrow and one wide channel and both are relatively shallow. The permeability is high (the aquifer material is gravel and sand) and the gradient is low. Approximately 94,000 gpd pass northward through this zone. The groundwater in this zone comes

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from beneath Basin F and contains high concentrations of pollutants. The second area, consisting of Zones 2 through 5, has lower permeabilities than Zone 1 since Zones 2-5 contain finer materials than those in Zone 1. The permeabilities are highest in the center of the area and are lower toward the east and west. Gradients are relatively high. Approximately 92,000 gpd pass northward through the area and the groundwater is not significantly polluted.

b. Cross section B-B' shows permeabilities increasing from west to east (Zones 1, 2, and 3) into channel 1, then decreasing permeabilties across the Denver formation shale High "B" (Zone 4), and, finally, higher permeabilities east of High "B" (Zones 5 and 6). Gradients west of High "B" are less than gradients east of the high. Aquifer materials west of High "B" are generally coarser gravels and sands than those east of it. Approximately 122,000 pgd pass through Zones 1, 2, and 3 and this groundwater is polluted. Almost 250,000 gpd pass through Zones 4, 5, and 6 and this groundwater is not significantly polluted.

c. Cross section C-C' has permeabilities increasing from west to east. Gradients are relatively high throughout the area. Zone 1 is east of and adjacent to clays and sandy clays overlying Denver shales and has low permeabilities. Zones 2 and 3 are on a relatively flat area west of channel 1. The aquifer materials are relatively thin sands and gravels and permeabilities are higher in Zones 2 and 3 than in Zone 1. Zone 4 is in and adjacent to channel 1. Permeabilities in Zone 4 are higher than those in Zones 1, 2, or 3 and the aquifer materials are composed of thick sands and gravels overlain by fine clays, silts, and sands. Approximately 283,000 gpd pass

through Zones 1, 2, and 3 and this groundwater is polluted. Over 600,000 gpd pass through Zone 4 and this water is not polluted.

PART IV: SUMMARY AND CONCLUSIONS

Summary

44. Groundwater in the study area flows in three general patterns which reflect geologic conditions. The patterns are delineated by water table gradients and flow directions. The first pattern is in an area from Basin F northeast to near the north boundary and is characterized by low gradients and a northeasterly flow. The second flow pattern is in the southeast part of the study area and is identified by relatively steep gradients and a northwesterly trend. The third flow pattern occurs at and just south of the north boundary and is characterized by a steep gradient and a northerly direction.

45. Comparison of water table data from 1957 to the present indicate that significant changes have occurred in water levels and flow directions in the vicinity of Basin F. Since 1957, water table elevations at the northern end of Basin F have dropped approximately 13 ft which has reduced the gradients north of Basin F and changed the flow direction from the north to the northeast. These changes have also influenced the flow pattern in section 24 where the northerly flow has changed to a northwesterly flow. Water table elevations in southeastern section 24 and along the northern boundary of RMA have shown only minor fluctuations.

46. A deflection pattern appears to be developing in the groundwater regime east and west of the pilot plant which indicates that groundwater may be flowing around the pilot plant. However, historical water table data show that the deflection pattern at the western end of the plant existed prior to the plant's construction. The deflection pattern east of the plant does not appear to have existed prior to plant construction. The dewatering rates at the eastern end of the plant have significantly exceeded the recharging rates at the eastern end of the plant which could cause the developing deflection pattern.

47. Field permeability tests conducted in the study area were pump tests and slug tests. The pump tests developed high permeabilities in and adjacent to channel 1 on the base of the alluvial aquifer map (Figure 5) and lower permeabilities were found outside of the channel. Slug test permeabilities were generally lower than those found with pump tests.

48. Alluvial aquifer water flow rates were computed for zones on cross sections A-A', B-B', and C-C'. The zone technique was used because permeabilities, gradients, and the presence of contaminants varied from one zone to another. Approximately 185,000 gpd, 360,000 gpd, and 885,000 gpd flow across cross section lines A-A', B-B', and C-C', respectively.

Conclusions

49. Based on this study the following conclusions are made:

a. The base of the alluvial aquifer is a weathered Denver formation shale except for several areas. In one large area and several small areas Denver sands occur above the Denver shales. These sands are in contact with alluvial aquifer materials and are considered as part of the alluvial aquifer in this study.

b. The weathered Denver formation shale at the base of the alluvial aquifer significantly influences the flow boundaries and flow directions of the alluvial aquifer groundwater.

c. Saturated thicknesses are greatest in channels and thin out on Denver highs. There are four dry areas in the alluvial aquifer where Denver highs occur.

d. North of the Denver High "A" in section 23, near the north boundary, the alluvial aquifer consists of clays and sandy clays which decrease the groundwater flow.

e. The alluvial aquifer is confined or semiconfined at several locations and most of these locations are near the north boundary.

f. Sands and gravels are generally coarser west of the Denver High "B" than those to the east.

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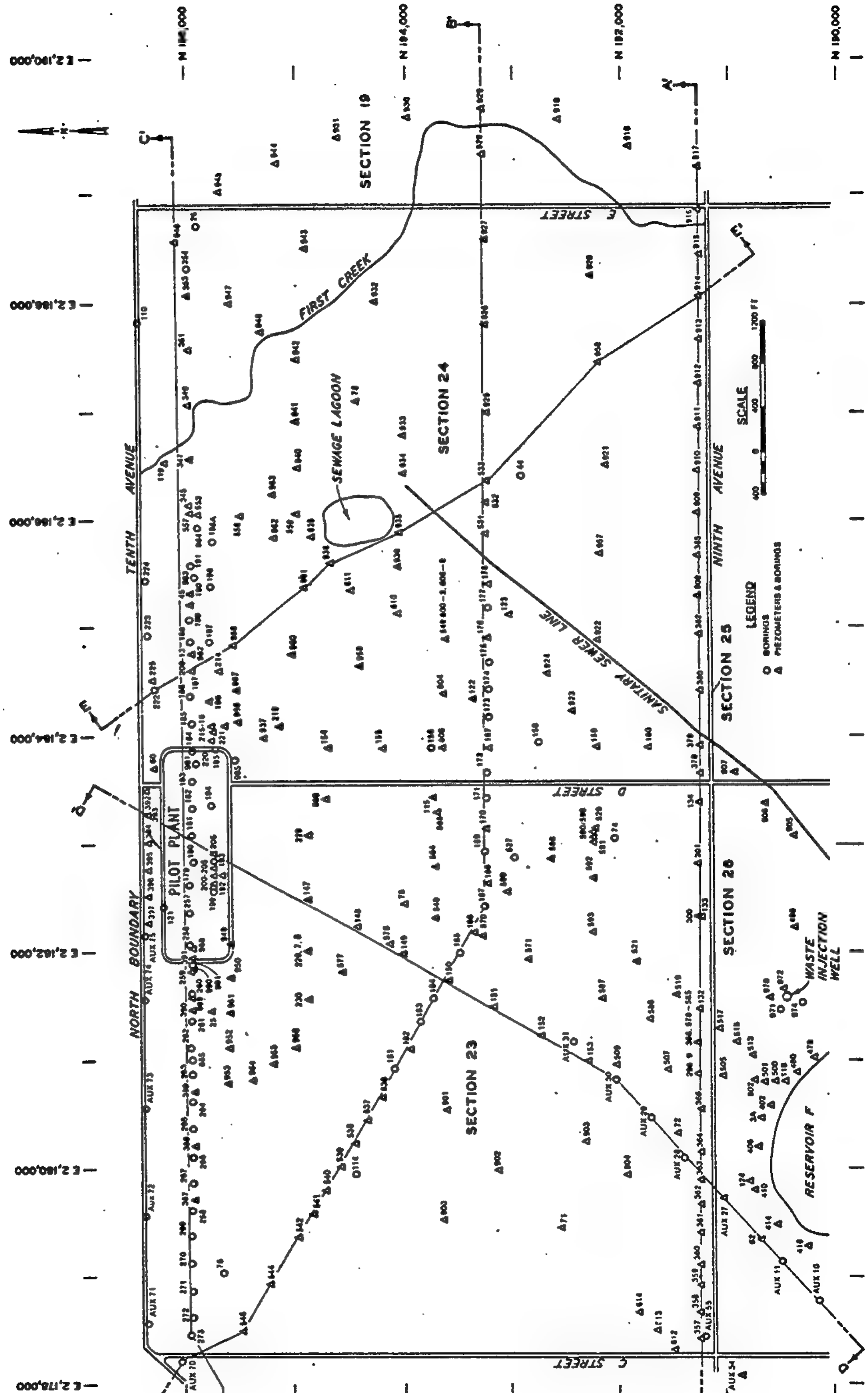
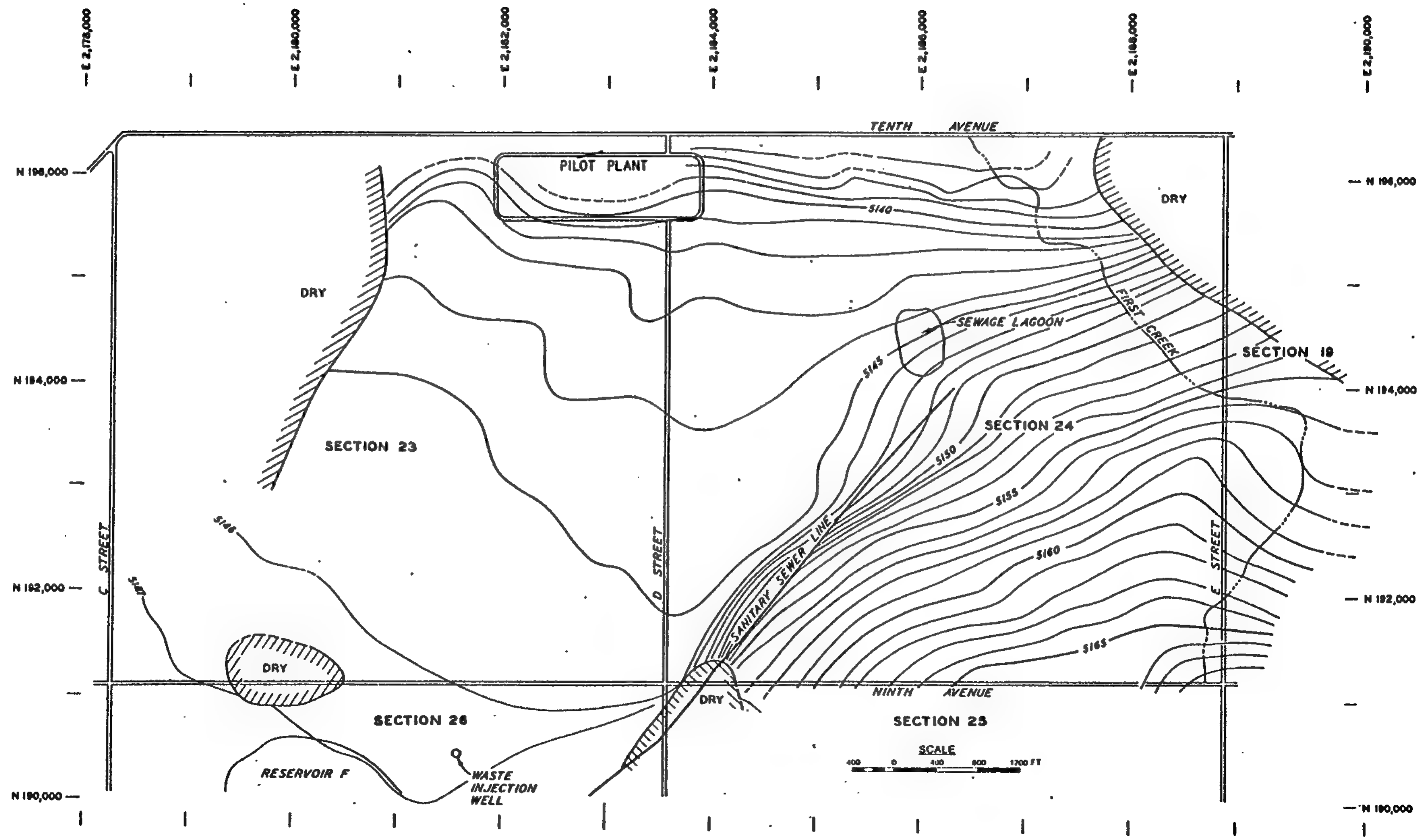


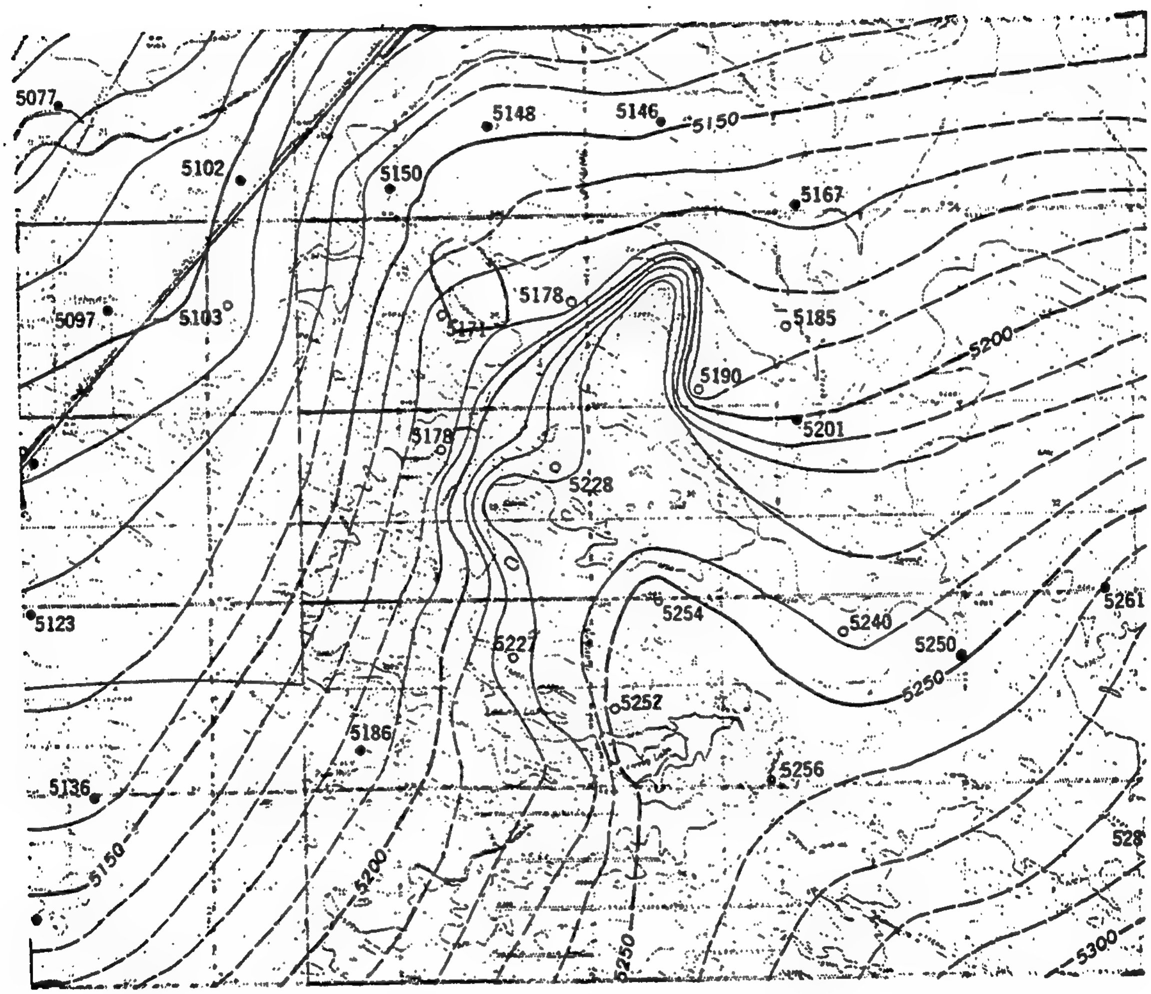
Boring, Piezometer, and Cross Section Locations.

Figure 1.



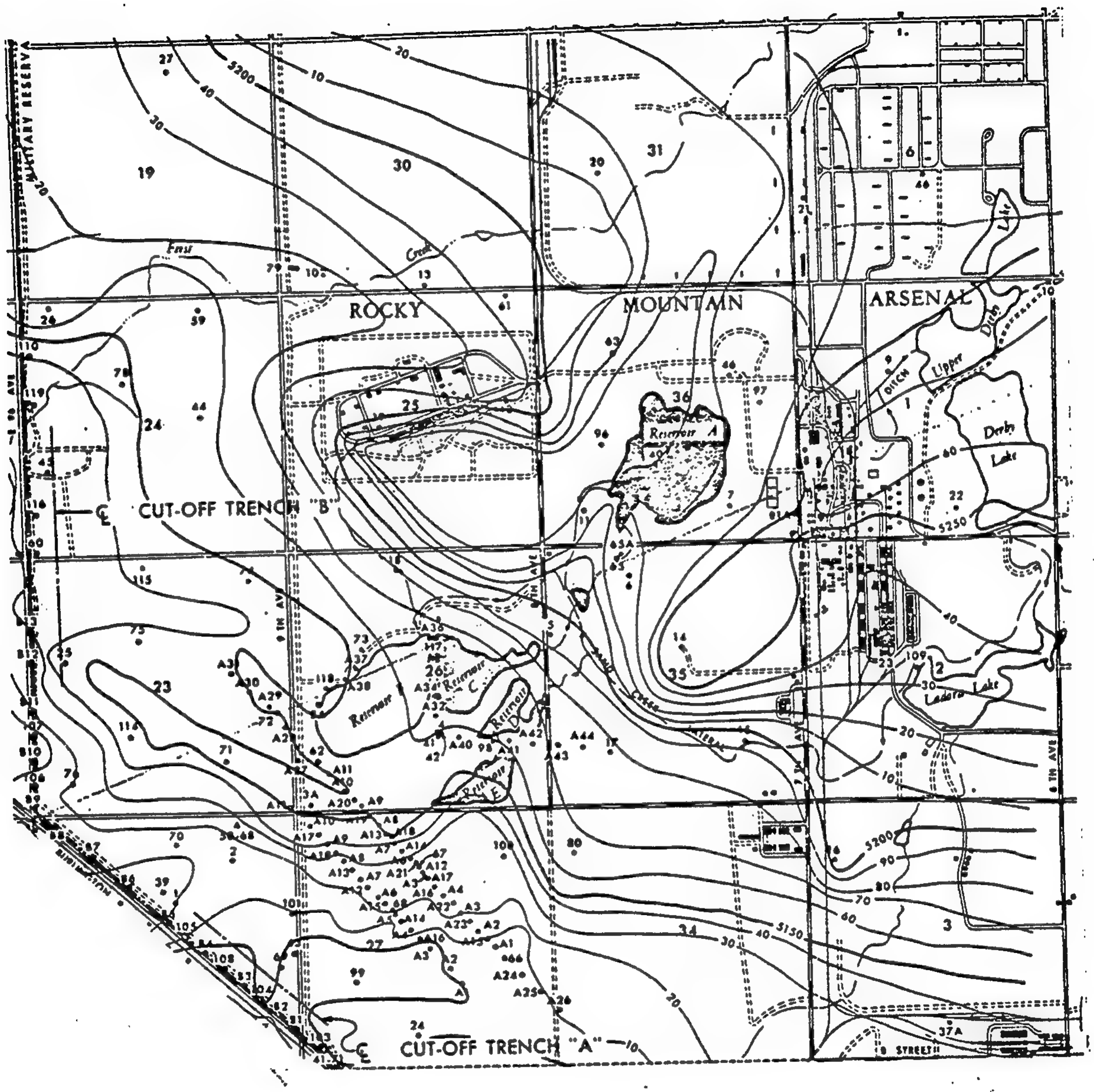
Alluvium Water Levels (May-June 1979)

Figure 2.



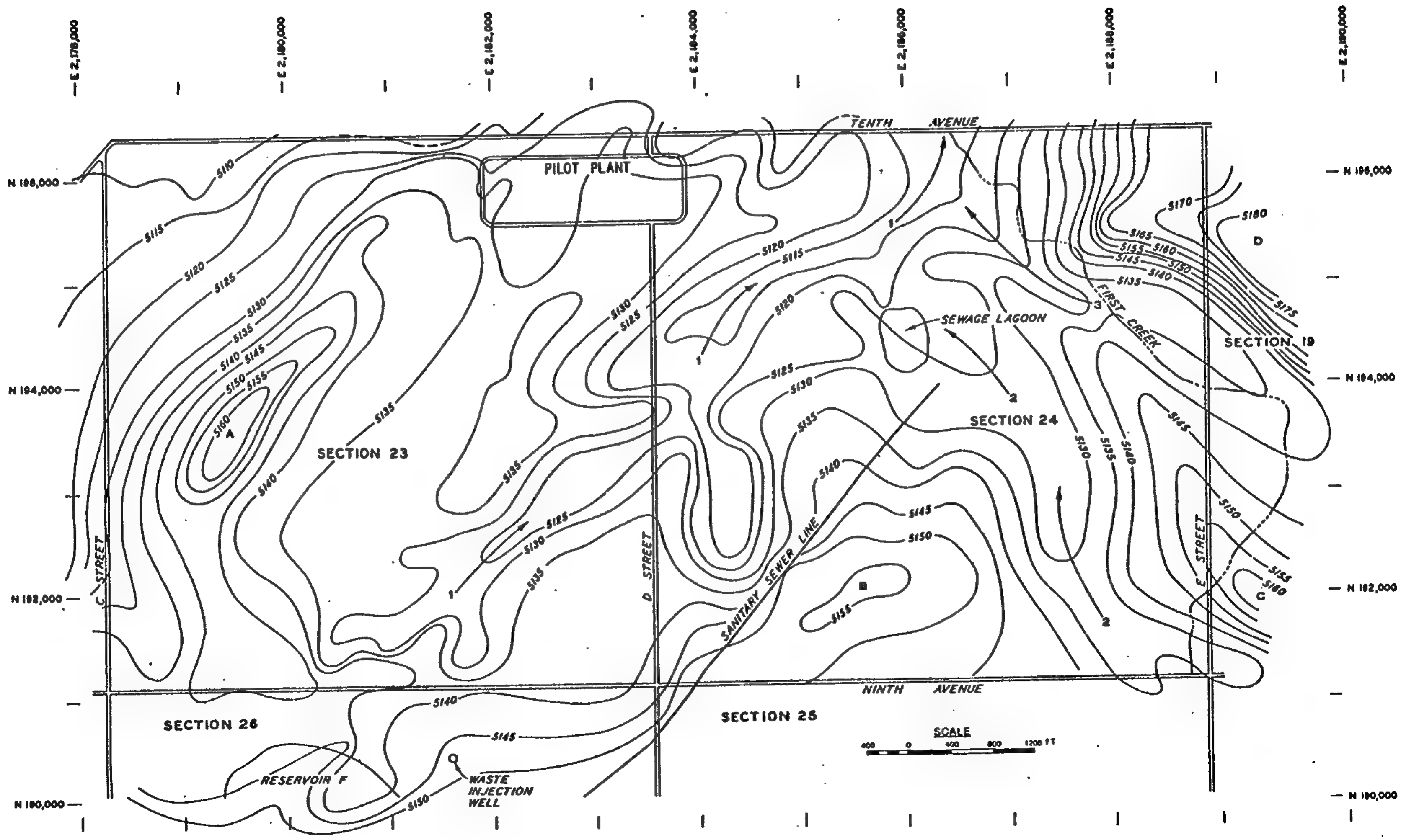
Alluvium Water Levels (1957)

Figure 3.



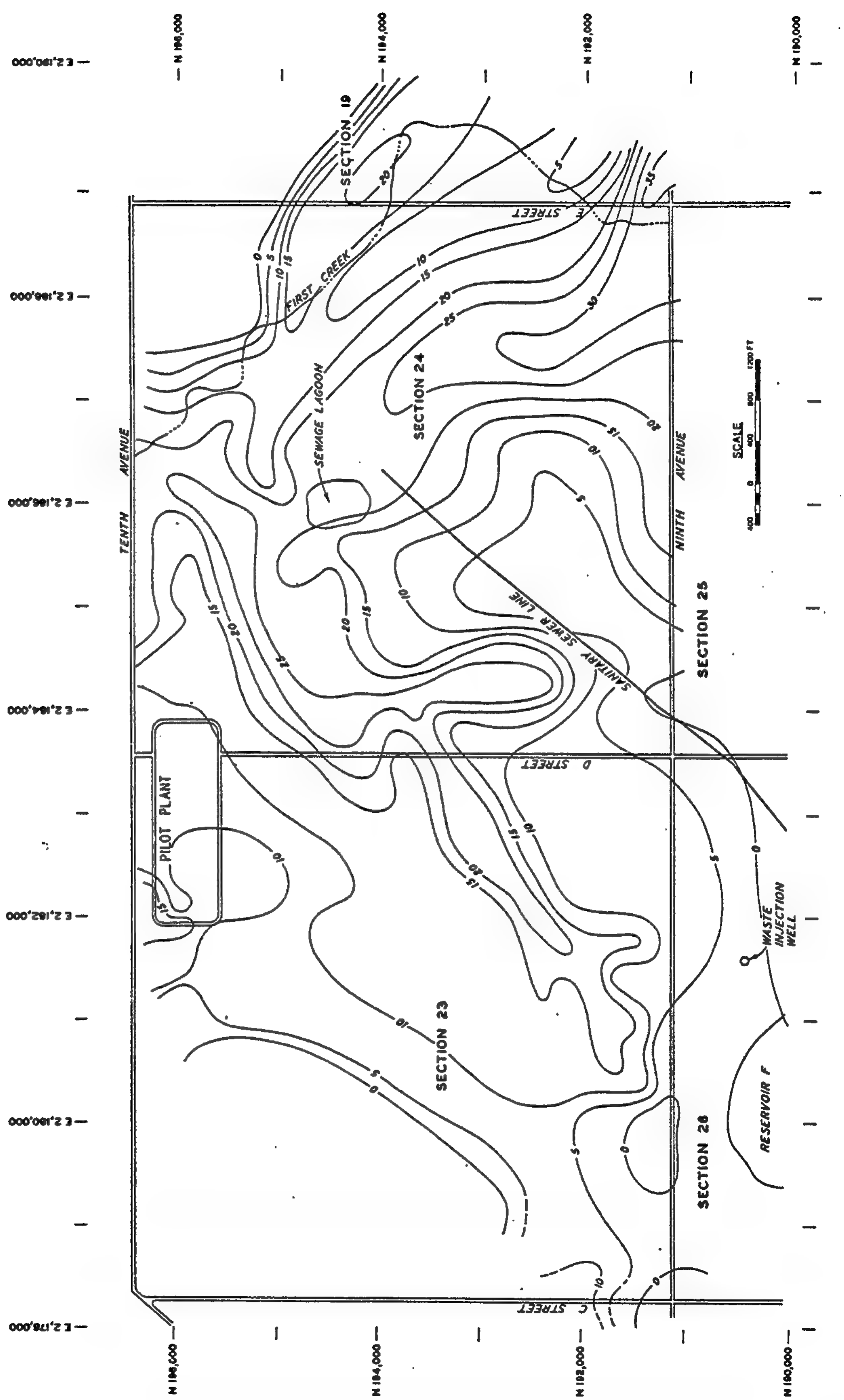
Alluvium Water Levels (1959-60)

Figure 4.



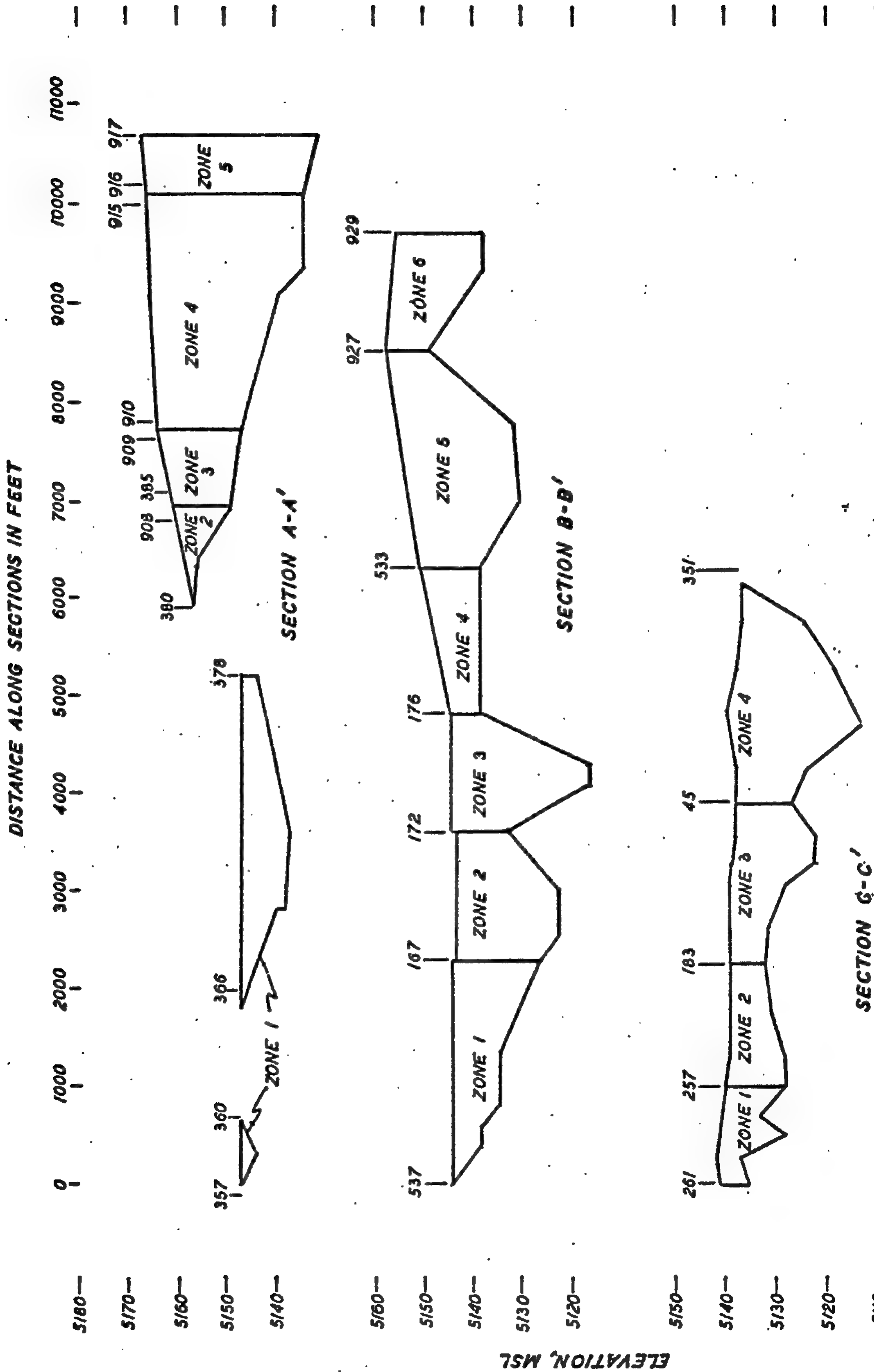
Base of the Alluvial Aquifer Contours.

Figure 5.



Saturated Alluvium Isopach (May-June 1979)

Figure 6.



Zone Locations by Cross Section

Figure 7.

Table 1

Selected Representative Water Table Elevations During the Study Period

Boring #	Elevations (Feet, MSL)			
	June 79	March 79	November 78	Other
358	5146.7	5147.1	—	—
368	5146.4	5146.7	—	5147.8 (Apr 78)
300	5145.6	5145.9	5146.9	5149.6 (Feb 77)
134	5145.5	5145.8	5146.5	5149.3 (Feb 77)- 5154.6 (Mar 76)
380	5156.8	5156.9	ND	ND
909	5163.7	5163.6	ND	ND
913	5165.8	5166.1	ND	ND
917	5168.3	5166.5	ND	ND
536	5144.8	5144.7	—	—
166	5144.9	5144.8	—	5146.6 (Apr 78)
157	5144.2	5143.3	5144.8	5147.3 (Feb 77)
178	5146.6	5146.3	—	5148.8 (Apr 78)
533	5152.2	5148.7	—	—
926	5157.3	5156.7	ND	ND
929	5156.4	5156.5	ND	ND
389	5130.1	5130.3	—	—
390	5141.3	5140.8	—	—
391	5140.2	5139.2	—	—
192/193	5139.3	5139.1	—	—
220	5140.4	5140.0	—	5141.2 (Feb 78)- 5142.3 (Mar 77)
214	5140.8	5140.0	—	5140.9 (Feb 78)- 5142.4 (Mar 77)
45	5138.6	5139.1	5137.4	5139.9 (Feb 77)
191	5138.1	5137.7	—	—
347	5137.6	5136.2	—	5137.2 (Apr 78)
351	5137.5	5137.8	—	5138.5 (Apr 78)

ND = Not Drilled

Table 1 (Continued)

Selected Representative Water Table Elevations During the Study Period

Boring #	Elevations (Feet, MSL)					
	June 79	March 79	October 78	April 78	June 77	March 77
25	5143.2	—	5143.8	5145.5	5147.1	5147.7
206	5139.3	5139.1	5138.9	5138.9	5141.2	5141.5
220	5140.4	5140.0	—	5141.0	5142.0	5142.1
60	5135.6	5135.8	5135.1	5136.1	5137.3	5136.5
230	5143.2	5144.0	5143.4	5145.3	5146.6	5146.8
147	5143.5	5143.2	—	5144.6	5145.7	5145.7
229	5143.7	5143.2	5143.7	5145.1	5145.8	5146.1

Table 2

Pilot Plant Dewatering and Recharge Totals Through August 1979*

Recharge Deficit (-) Surplus (+)	+0.24	+2.6	+0.8	-0.7	-2.8	-2.7
Recharge Total (Million Gallons)	1.34	4.4	5.4	2.3	5.9	8.3
Recharge Well (Set)	322 323	324 325	326 327	328 329	330 331	332 333
Dewatering Well	321	320	319	318	317	316
Dewatering Total (Million Gallons)	1.1	1.8	4.6	3.0	8.7	11.0

*Source: Pilot System Update, 5 September 1979, RMA

Table 3

Summarized Pump Test Results

Pump Test		Permeabilities (gpd/ft^2)
345	Well:	2357
	East line:	4100
	South line:	3450
368	Well:	12000
	West line:	6930
	East line:	6950
529	Well:	11500
	West line:	8250
	Northwest line:	6600
548	Well:	1120
	Northwest line (0-50 ft):	1290
	Northwest line (50-100 ft):	1380
	Southwest line (0-50 ft):	1320
	Southwest line (50-1000 ft):	1980
	East line (0-50 ft):	1450
	East line (50-1000 ft):	1710
549	Well:	430
	West line (0-50 ft):	240
	West line (50-1000 ft):	1135
	Northeast line (0-80 ft):	250
	Northeast line (80-100 ft):	1090

Table 4

New Borings and Selected Other Boring and Piezometer Data with Field Permeability Test Results

Boring No.	Date Drilled	Ground Elevation (ft, MSL)	Base of Alluvial Aquifer (ft, MSL)	Screen Elevations (ft, MSL)	Saturated Thickness (ft)	Permeability* Test Type	Storativity α	Permeability (cm/sec $\times 10^{-4}$)	Permeability (gpd/ft^2)
345	Feb 78	5140.60	5113.6	5120.3–5116.3	24.4	RHT	10^{-2}	0.151	0.32
347	Feb 78	5141.72	5118.7	5122.3–5118.3	18.6	RHT	10^{-4}	0.386	0.82
349	Feb 78	5149.07	5125.0	5128.7–5124.7	11.8	RHT	10^{-10}	399.0	846.0
351	Feb 78	5178.22	5153.2	5133.5–5129.5	-0-	RHT**	10^{-6}	0.297	0.63
378	Feb 79	5187.12	5143.1	5149.7–5141.7	3.0	FHT	10^{-4}	16.4	34.8
379	Feb 79	5188.44	5156.2	5156.8–5148.8	0.5	NT	—	—	—
380	Feb 79	5190.65	5151.6	5157.8–5149.8	5.2	FHT	10^{-12}	0.371	0.79
382	Feb 79	5192.30	5153.3	5159.9 5151.9	5.2	FHT	10^{-2}	2.36	5.0
385	Feb 79	5187.82	5146.8	5159.0–5143.0	15.5	RHT	10^{-5}	52.6	111.5
402	Nov 77	5189.35	5144.3	5148.6–5144.6	2.3	FHT	10^{-1}	3.75	7.95
406	Nov 77	5192.48	5143.9	5144.5–5140.5	2.5	FHT	10^{-1}	36.7	77.8
410	Nov 77	5188.81	5144.0	5148.6–5144.6	2.8	FHT	10^{-4}	59.9	127.0

* RHT = rising head test, FHT = falling head test, NT = not tested.
** Screen in Denver shales, clays, or other Denver formation materials not included in the alluvial aquifer.

Table 4

New Borings and Selected Other Boring and Piezometer Data with Field Permeability Test Results

Boring No.	Date Drilled	Ground Elevation (ft, MSL)	Base of Alluvial Aquifer (ft, MSL)	Screen Elevations (ft, MSL)	Saturated Thickness (ft)	Permeability* Test Type	Storativity α	Permeability (cm/sec x 10^{-4})	Permeability (gpd/ft^2)
414	Nov 77	5190.26	5143.3	5146.7–5142.7	3.4	FHT	10^{-5}	113.2	240.0
418	Nov 77	5193.57	5143.1	5146.8–5142.8	3.6	FHT	10^{-4}	0.769	1.63
480	Jan 78	5195.32	5137.7	5138.5–5134.5	9.2	FHT	10^{-4}	17.9	37.9
532	Mar 79	5167.25	5134.2	5139.9–5131.9	16.7	RHT	—	131.0	277.0
533	Jul 78	5164.94	5140.9	5143.9–5139.9	11.3	NT	—	—	—
604	Apr 78	5167.60	5128.6	5137.7–5133.7	15.–	RHT	—	2484.0	5260.0
605	Apr 78	5169.80	5119.8	5125.6–5121.6	24.2	RHT	—	1113.0	2360.0
900	Feb 79	5179.94	5161.6	5167.8–5159.8	-0-	NT	—	—	—
901	Feb 79	5189.08	5136.1	5150.5–5134.5	9.6	NT	—	—	—
902	Feb 79	5188.63	5136.0	5149.6–5133.6	9.8	NT	—	—	—
903	Feb 79	5189.24	5132.7	5151.2–5138.8	12.7	FHT	10^{-6}	4.5	9.54
904	Feb 79	5193.59	5142.8	5155.5–5139.5	2.9	NT	—	—	—

* RHT = rising head test, FHT = falling head test, NT = not tested.

** Screen in Denver shales, clays, or other Denver formation materials not included in the alluvial aquifer.

Table 4

New Borings and Selected Other Boring and Piezometer Data with Field Permeability Test Results

Boring No.	Date Drilled	Ground Elevation (ft, MSL)	Base of Alluvial Aquifer (ft, MSL)	Screen Elevations (ft, MSL)	Saturated Thickness (ft)	Permeability* Test Type	Storativity α	Permeability (cm/sec x 10^{-4})	Permeability (gpd/ft^2)
905	Mar 79	5197.36	5157.7	5162.0–5152.0	0.2	FHT	10^{-2}	0.508	1.08
906	Mar 79	5195.11	5153.1	5160.1–5150.1	2.6	FHT	10^{-10}	3.12	6.62
907	Mar 79	5192.58	5150.0	5164.1–5152.1	2.4	NT	—	—	—
908	Feb 79	5189.28	5149.8	5161.5–5149.5	10.9	FHT	10^{-4}	4.92	10.4
909	Feb 79	5189.01	5147.8	5158.0–5142.0	15.9	RHT	10^{-7}	35.6	75.5
910	Feb 79	5183.93	5146.4	5158.9–5143.9	18.8	RHT	10^{-7}	162.0	343.0
911	Feb 79	5181.29	5139.0	5151.1–5135.1	25.4	RHT	10^{-4}	63.7	135.0
912	Feb 79	5181.42	5142.4	5160.0–5144.0	23.5	RHT	—	99.1	210.0
913	Mar 79	5181.92	5139.9	N/A	25.9	NT	—	—	—
914	Feb 79	5181.26	5133.3	5147.4–5131.4	32.6	RHT	10^{-9}	185.0	392.0
915	Feb 79	5172.91	5135.2	5147.9–5131.9	32.6	RHT	10^{-5}	86.8	184.0
916	Mar 79	5172.09	5135.2	5148.5–5132.5	34.5	RHT	10^{-2}	19.1	40.5

* RHT = rising head test, FHT = falling head test, NT = not tested.
** Screen in Denver shales, clays, or other Denver formation materials not included in the alluvial aquifer.

Table 4

New Borings and Selected Other Boring and Piezometer Data with Field Permeability Test Results

Boring No.	Date Drilled	Ground Elevation (ft, MSL)	Base of Alluvial Aquifer (ft, MSL)	Screen Elevations (ft, MSL)	Saturated Thickness (ft)	Permeability* Test Type	Storativity α	Permeability (cm/sec $\times 10^{-4}$)	Permeability (gpd/ft^2)
917	Feb 79	5175.70	5131.7	5138.7–5130.7	36.6	RHT	10^{-2}	1.74	3.69
918	Feb 79	5179.89	5162.5	5166.9–5158.9	0.3	NT	—	—	—
919	Feb 79	5163.64	5145.2	5150.6–5142.6	13.6	RHT	10^{-3}	28.2	59.8
920	Mar 79	5171.67	5143.2	5151.2–5141.7	19.7	RHT	10^{-10}	215.0–749.0	456.0–1590.0
921	Mar 79	5173.55	5151.4	5143.3–5134.2	8.3	RHT**	10^{-4}	25.6	54.3
922	Mar 79	5180.21	5152.4	5149.2–5140.2	0.9	NT	—	—	—
923	Mar 79	5176.17	5116.2	N/A	28.4	NT	—	—	—
924	Mar 79	5172.95	5126.0	5137.9–5127.9	16.0	FHT	—	623.0	1320.0
925	Mar 79	5171.50	5132.0	5143.7–5127.7	22.5	RHT	10^{-9}	7.84	16.6
926	Mar 79	5168.78	5132.0	5140.5–5128.5	25.3	RHT	10^{-10}	353.0	748.5
927	Feb 79	5164.99	5150.1	5157.0–5149.0	9.1	NT	—	—	—
928	Mar 79	5160.84	5143.5	5139.8–5130.8	13.9	RHT**	10^{-2}	6.02	12.8

* RHT = rising head test, FHT = falling head test, NT = not tested.
** Screen in Denver shales, clays, or other Denver formation materials not included in the alluvial aquifer.

Table 4

New Borings and Selected Other Boring and Piezometer Data with Field Permeability Test Results

Boring No.	Date Drilled	Ground Elevation (ft, MSL)	Base of Alluvial Aquifer (ft, MSL)	Screen Elevations (ft, MSL)	Saturated Thickness (ft)	Permeability* Test Type	Storativity α	Permeability (cm/sec x 10^{-4})	Permeability (gpd/ft^2)
929	Mar 79	5161.00	5138.2	5138.1–5121.0	18.2	RHT**	10^{-4}	12.3	26.1
930	Feb 79	5163.95	5137.5	5141.9–5133.9	18.2	RHT	10^{-4}	1.62	3.43
931	Mar 79	5189.57	5167.8	5174.2 5165.0	-0-	NT	—	—	—
932	Mar 79	5155.04	5142.8	5144.4–5135.4	8.7	RHT	10^{-6}	990.0	2100.0
933	Mar 79	5159.13	5125.9	5131.6–5119.6	24.8	RHT	10^{-12}	300.0	636.0
934	Mar 79	5158.70	5127.4	5138.1–5126.1	21.7	RHT	10^{-5}	8.24	17.5
935	Feb 79	5155.58	5126.4	5136.6–5120.6	20.6	RHT	10^{-5}	64.3	136.0
936	Feb 79	5157.64	5132.3	5133.8–5117.8	13.2	RHT	10^{-8}	48.8	103.0
937	Mar 79	5159.26	5127.0	5132.3–5125.3	15.5	RHT	10^{-4}	4.88	10.3
938	Mar 78	5150.65	5126.9	5133.6–5125.6	16.8	RHT	10-6	142.0	301.0
939	Mar 79	5148.40	5120.5	5126.4–5118.4	22.7	RHT	10^{-1}	0.007	0.0148
940	Feb 79	5144.97	5123.8	5128.0–5120.0	20.1	NT	—	—	—

* RHT = rising head test, FHT = falling head test, NT = not tested.

** Screen in Denver shales, clays, or other Denver formation materials not included in the alluvial aquifer.

Table 4

New Borings and Selected Other Boring and Piezometer Data with Field Permeability Test Results

Boring No.	Date Drilled	Ground Elevation (ft, MSL)	Base of Alluvial Aquifer (ft, MSL)	Screen Elevations (ft, MSL)	Saturated Thickness (ft)	Permeability* Test Type	Storativity α	Permeability (cm/sec x 10^{-4})	Permeability (gpd/ft^2)
941	Feb 79	5145.06	5130.9	5138.1–5130.1	12.8	RHT	10^{-4}	222.0	471.0
942	Feb 79	5148.47	5130.5	5136.5–5128.5	14.4	RHT	10^{-9}	15.3	32.4
943	Feb 79	5168.48	5133.9	5141.5–5133.5	15.9	NT	—	—	—
944	Mar 79	5204.20	5182.4	5188.2–5179.2	-0-	NT	—	—	—
945	Mar 79	5208.27	5175.3	5183.3–5173.4	-0-	NT	—	—	—
946	Feb 79	5187.24	5164.7	5155.3–5147.3	-0-	NT	—	—	—
947	Feb 79	5181.55	5168.7	5134.5–5126.5	-0-	NT	—	—	—
948	Feb 79	5155.19	5147.6	5151.7–5143.7	-0-	NT	—	—	—
949	Apr 79	5150.39	5128.4	5128.4–5124.4	13.0	RHT**	10^{-10}	0.546	1.16
950	Apr 79	5152.27	5134.7	5136.3–5132.3	8.2	RHT	10^{-7}	13.3	28.2
951	Apr 79	5154.55	5135.5	5138.5–5734.5	8.1	RHT	10^{-10}	39.5	83.8
952	Apr 79	5154.23	5136.6	5138.2–5134.2	7.2	RHT	10^{-3}	0.14	0.30

* RHT = rising head test, FHT = falling head test, NT = not tested.

** Screen in Denver shales, clays, or other Denver formation materials not included in the alluvial aquifer.

Table 4
New Borings and Selected Other Boring and Piezometer Data with Field Permeability Test Results

Boring No.	Date Drilled	Ground Elevation (ft, MSL)	Base of Alluvial Aquifer (ft, MSL)	Screen Elevations (ft, MSL)	Saturated Thickness (ft)	Permeability* Test Type	Storativity α	Permeability (cm/sec x 10^{-4})	Permeability (gpd/ft^2)
953	Apr 79	5151.25	5142.3	5145.9–5141.9	-0-	NT	—	—	—
954	Apr 79	5158.26	5147.8	5151.3–5147.3	-0-	NT	—	—	—
955	Apr 79	5166.79	5138.3	5144.8–5136.8	5.6	NT	—	—	—
956	Apr 79	5173.12	5138.9	5136.1–5128.1	5.1	NT	—	—	—
957	Mar 79	5178.48	5156.5	5160.5–5148.5	1.7	NT	—	—	—
958	Mar 79	5177.57	5130.6	5141.0–5127.6	31.1	RHT	10^{-3}	44.2	93.7
959	Mar 79	5164.16	5121.8	5127.2–5119.2	21.7	RHT	10^{-10}	40.0	84.8
960	Mar 79	5160.95	5118.9	5123.9–5115.9	23.6	RHT	10^{-1}	0.29	0.61
961	Mar 79	5152.82	5124.8	5130.8–5122.8	17.9	RHT	—	106.0	225.0
962	Mar 79	5146.71	5118.3	5124.7–5116.7	23.9	NT	—	—	—
963	Mar 79	5144.58	5125.8	5132.6 5124.6	16.7	NT	—	—	—
965	Mar 79	5156.56	5129.2	5126.6–5121.6	12.1	RHT**	10^{-2}	6.73	14.3

* RHT = rising head test, FHT = falling head test, NT = not tested.
** Screen in Denver shales, clays, or other Denver formation materials not included in the alluvial aquifer.

Table 4

New Borings and Selected Other Boring and Piezometer Data with Field Permeability Test Results

Boring No.	Date Drilled	Ground Elevation (ft, MSL)	Base of Alluvial Aquifer (ft, MSL)	Screen Elevations (ft, MSL)	Saturated Thickness (ft)	Permeability* Test Type	Storativity	Permeability (cm/sec x 10^{-4})	Permeability (gpd/ft^2)
966	Mar 79	5156.16	5128.9	5131.2–5126.2	12.9	NT	—	—	—
967	Mar 79	5155.38	5128.1	5135.2–5125.2	13.5			167.0	354
968	Mar 79	5149.45	5126.7	5124.5 5119.5	14.9	RHT**	10^{-8}	4.65	9.86
969	Mar 79	5156.85	5129.6	5134.8–5126.8	13.3	RHT	10^{-3}	1.57	3.32
970	Apr 79	5187.35	5145.1	5122.3–5102.3	1.9	NT	—	—	—
971	Apr 79	5187.34	5145.3	none	Boring	Grouted	—	—	—
972	Apr 79	5187.79	5147.3	5142.8–5132.8	0	RHT**	10^{-1}	0.204	0.433
973	Apr 79	5190.84	5138.4	none	Boring	Grouted	—	—	—
974	Apr 79	none	none	none	Boring	Grouted	—	—	—

* RHT = rising head test, FHT = falling head test, NT = not tested.

** Screen in Denver shales, clays, or other Denver formation materials not included in the alluvial aquifer.

Table 5

Saturated Cross Section Areas With Adjustments

Zone	Total Saturated Area (ft^2)	Adjustment (ft^2)	Adjusted Total
Line A-A'			
1	19,800	-0-	19,800
2	4,900	-0-	4,900
3	11,400	2,000	9,400
4	62,500	3,700	58,800
5	20,700	1,200	19,500
TOTALS	119,300	6,900	112,400
Line B-B'			
1	21,200	3,000	18,200
2	22,400	-0-	22,400
3	24,100	-0-	24,100
4	12,600	-0-	12,600
5	42,800	4,000	38,800
6	17,600	6,900	10,700
TOTALS	140,700	13,900	126,800
Line C-C'			
1	9,500	4,300	5,200
2	10,900	2,000	8,900
3	18,100	5,000	13,100
4	37,600	14,200	23,400
TOTALS	76,100	25,500	50,600

Table 6

Water Flow Rates Across Cross Sections By Zone

Cross Section	Zone	Permeability gpd/ft^2	Area ft^2	Gradient	Flow gpd
A-A'	1	7,000 (Pump Test 368)	19,800	0.0006 0.00075 average	83,200 104,000 93,600
	2	10.5 (Slug Test 908)	4,900	0.0058 0.0075 average	300 400 350
	3	93.5 (Slug Test 385 & 909 average)	9,400	0.0055	4,800
	4	252 (Slug Test 910, 911 912, 914, 915 average)	58,800	0.0044 0.0068 average	65,200 100,800 83,000
	5	22.1 (Slug Test 916 & 917 average)	19,500	0.0069 0.0096 average	3,000 4,100 3,550
B-B'	1	1400 (Pump Test 548, northwest line)	18,200	0.00067	17,100
	2	1700 (Pump Test 548, east line)	22,400	0.00067 0.00083 average	25,500 31,600 28,550
	3	3800 (Slug Test 604, 605 average)	24,100	0.00083	76,000
	4	277.0 (Slug Test 532)	12,600	0.0062	21,600
	5	748.5 (Slug Test 926)	38,800	0.0062 0.0075 average	180,100 217,800 198,950
	6	748.5 (Slug Test 926)	10,700	0.0035	28,000
C-C'	1	83.8 (Slug Test 951)	5,200	0.0024 0.0045 average	1,000 2,000 1,500

(Continued)

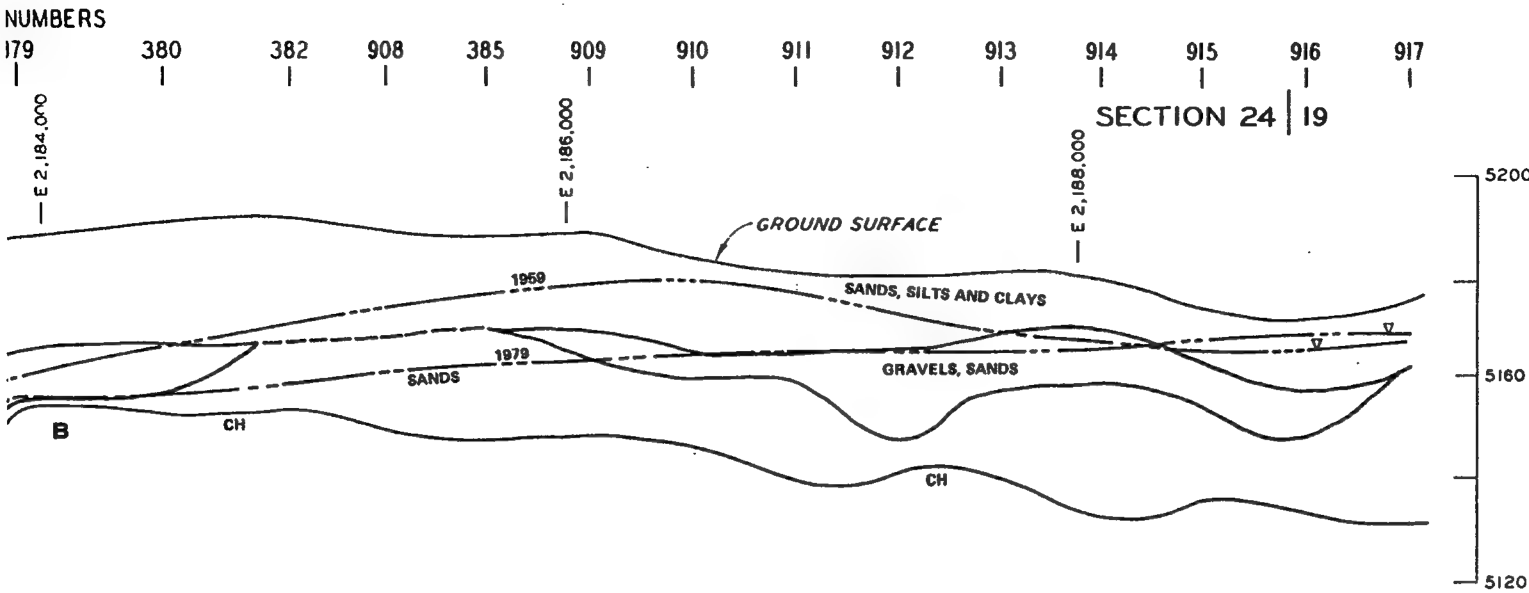
Table 6 (Continued)

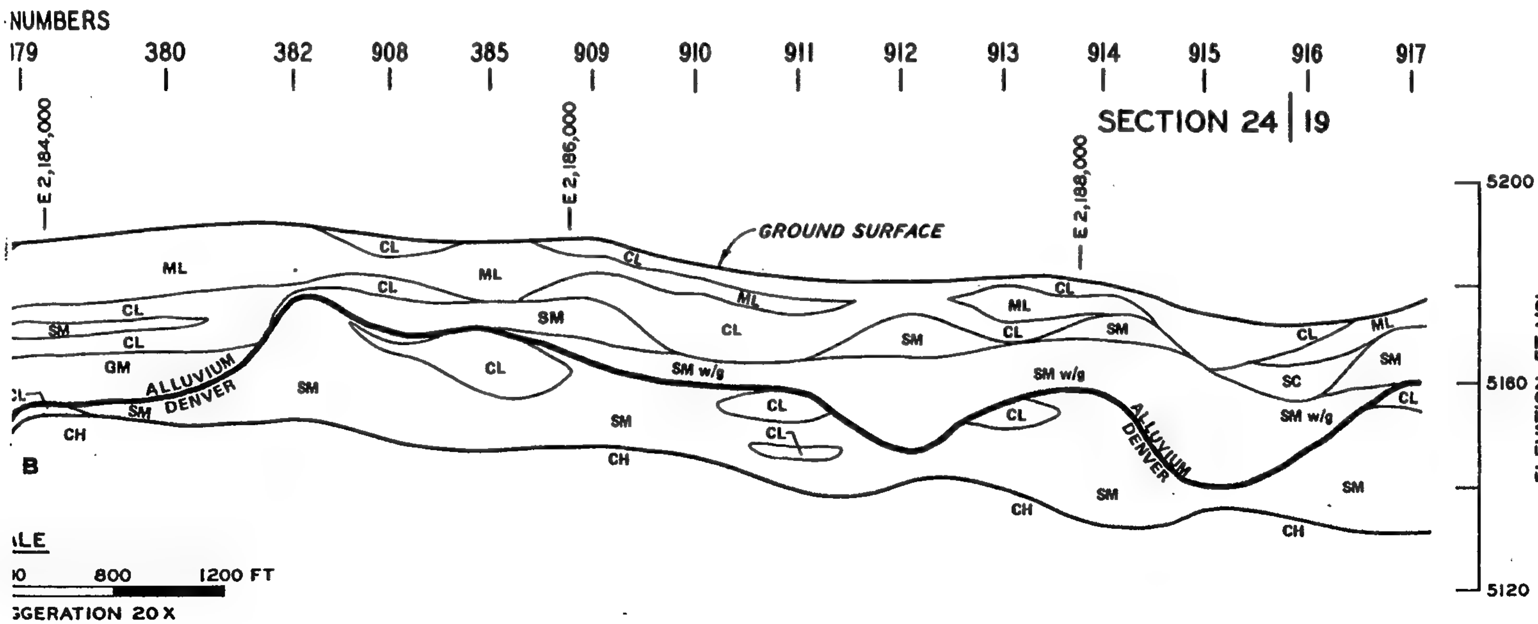
Water Flow Rates Across Cross Sections By Zone

Cross Section	Zone	Permeability gpg/ft^2	Area ft^2	Gradient	Flow gpd
C–C'	2	1700 (Pump Test 548 line average)	8,900	0.0054 0.0063 average	81,700 95,300 88,500
	3	1700 (Pump Test 548 line average)	13,100	0.0083 0.009 average	184,800 200,400 192,600
	4	3780 (Pump Test 345 line average)	23,400	0.0068	601,500

TOTALS

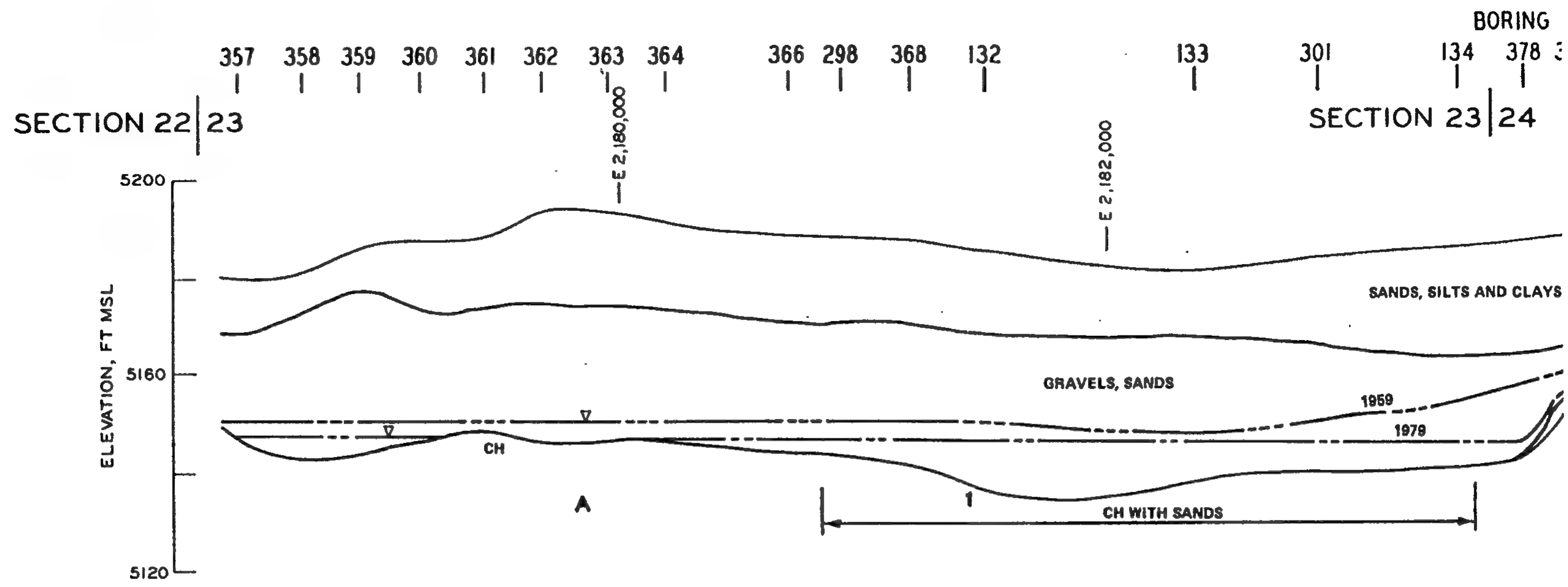
Cross Section	High Flow	Low Flow	Average
A–A'	214,100 gpd	156,500 gpd	185,300 gpd
B–B'	392,100 gpd	348,300 gpd	370,200 gpd
C–C'	899,200 gpd	869,000 gpd	884,100 gpd

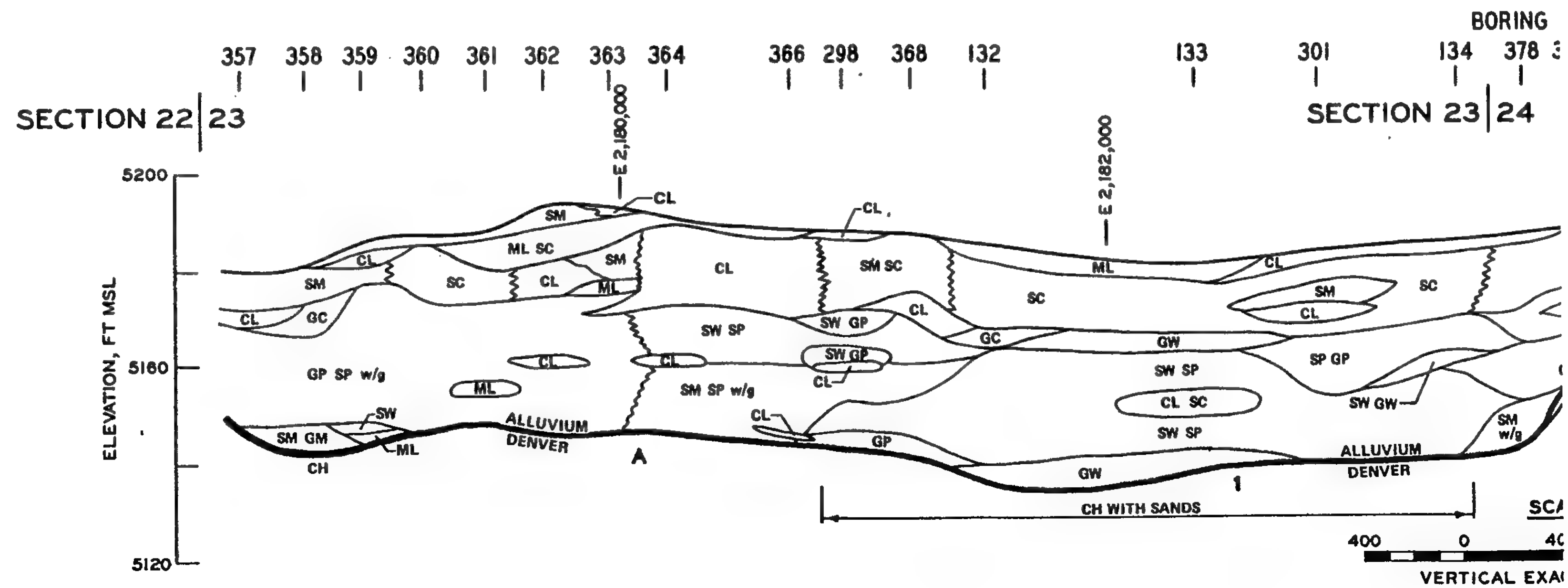




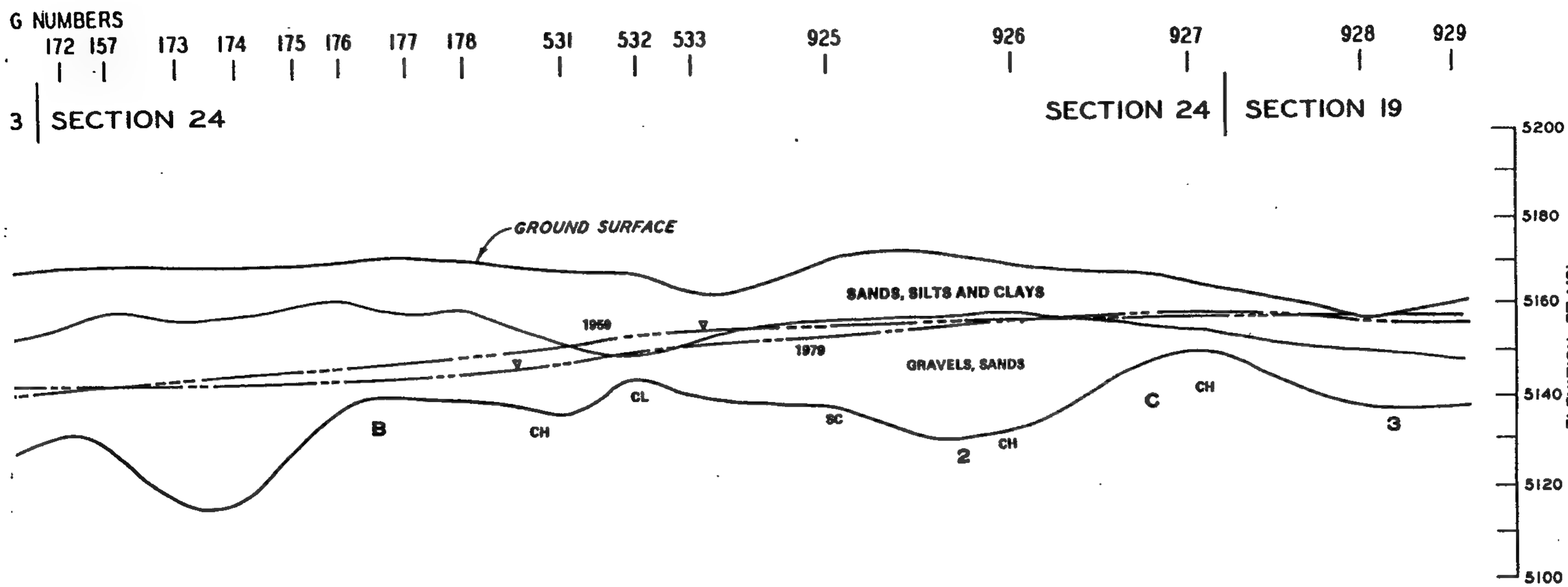
: Cross Sections A-A'
Water Levels.

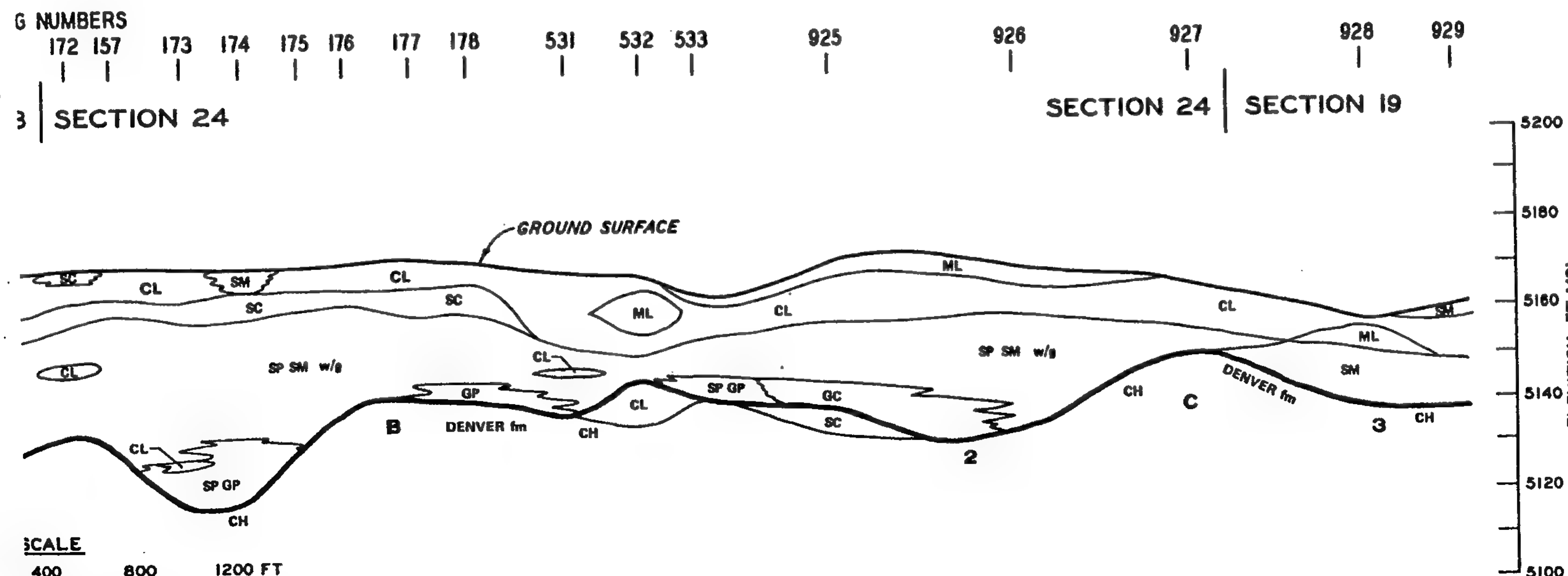
PLATE 1





General and Stratigraphic
with 1959 and 1979

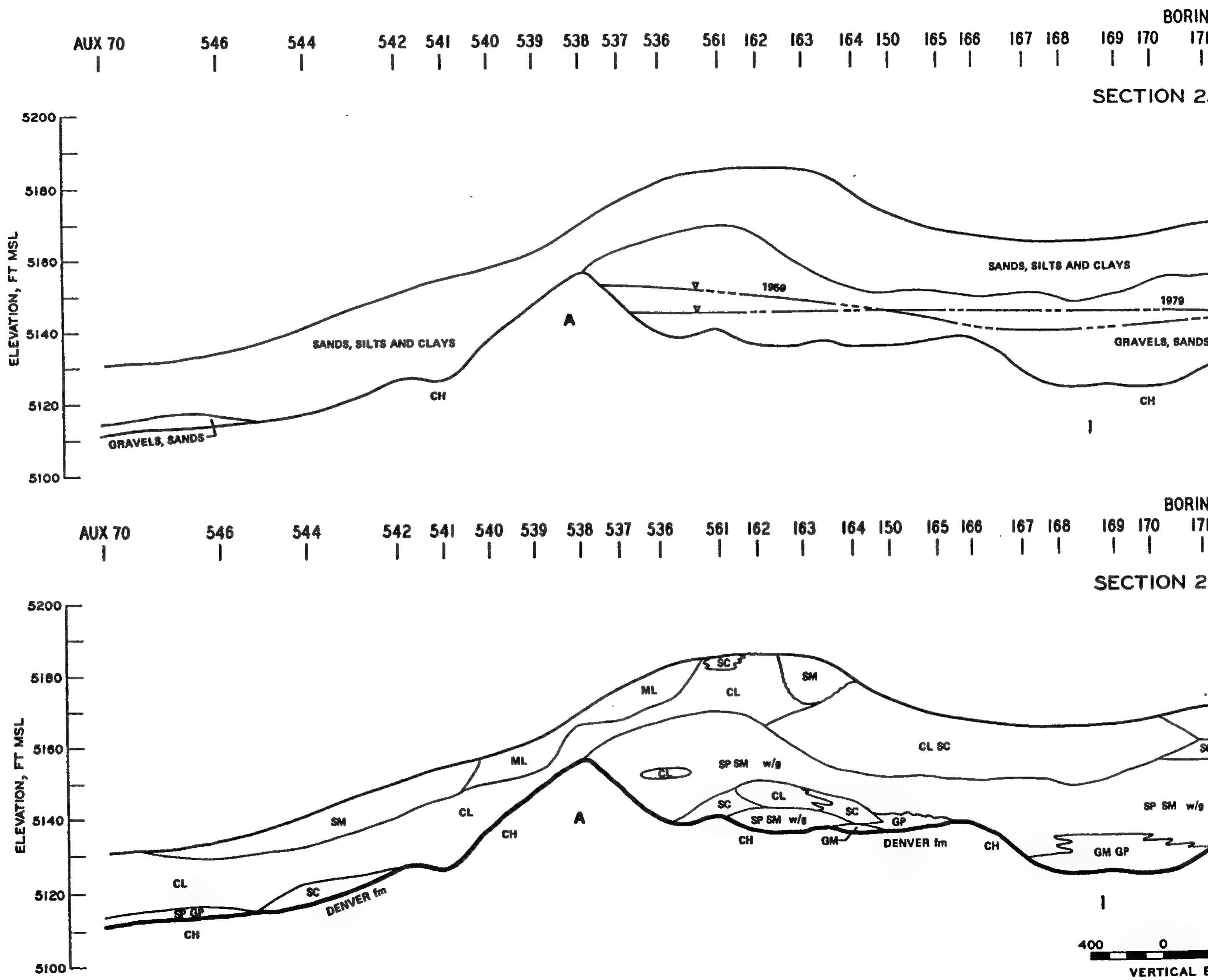




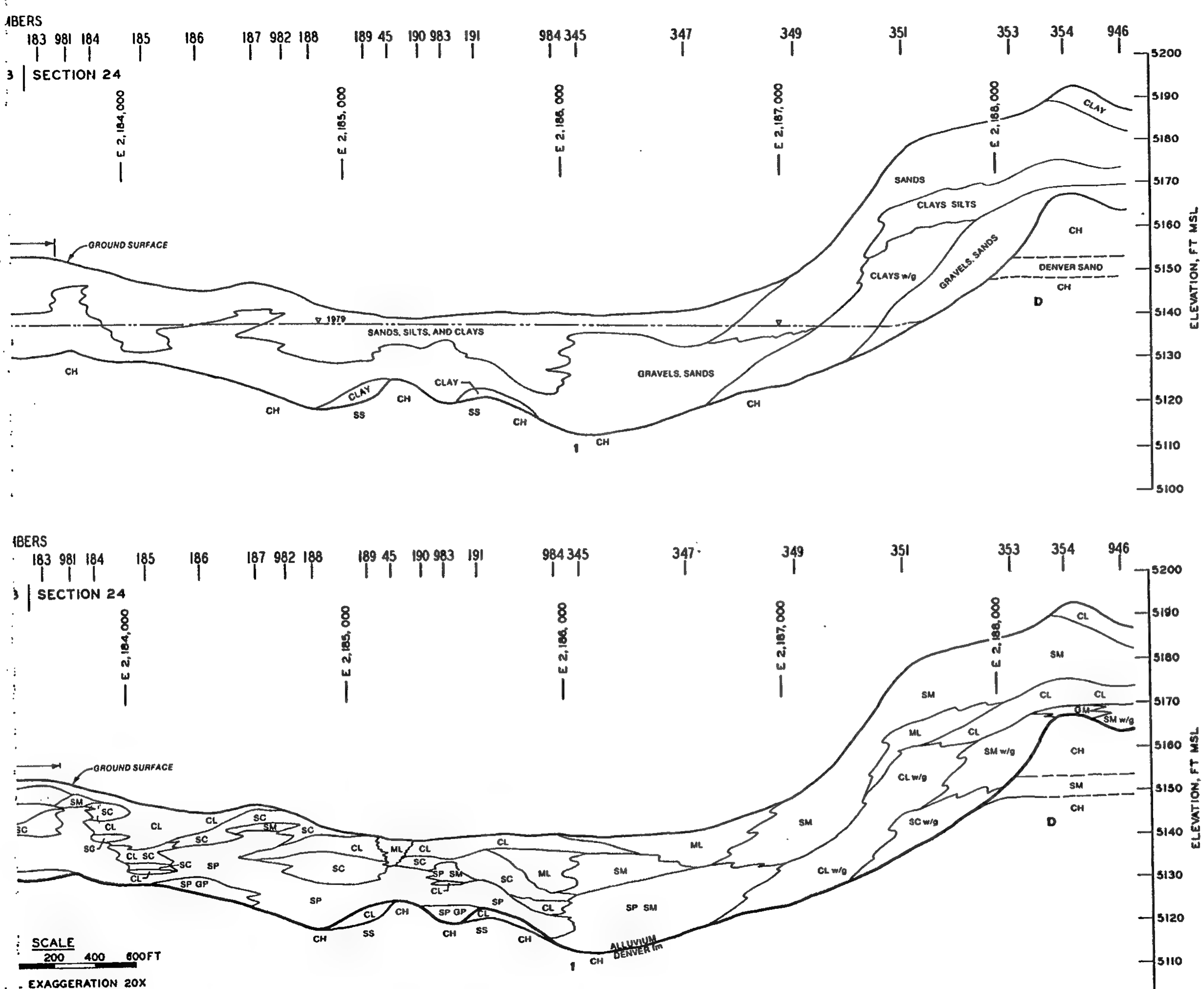
SCALE
400 800 1200 FT
AGGERATION 20X

aphic Cross Sections B-B'
1979 Water Levels.

PLATE 2

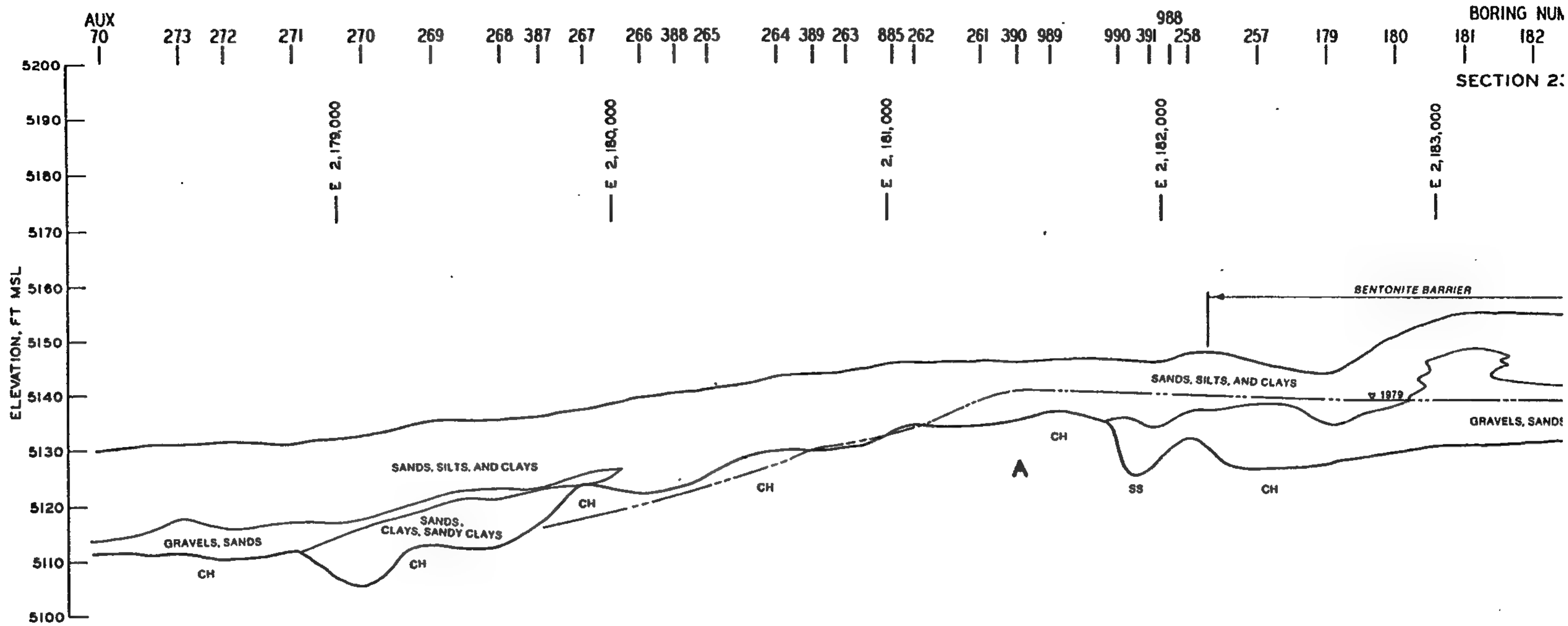


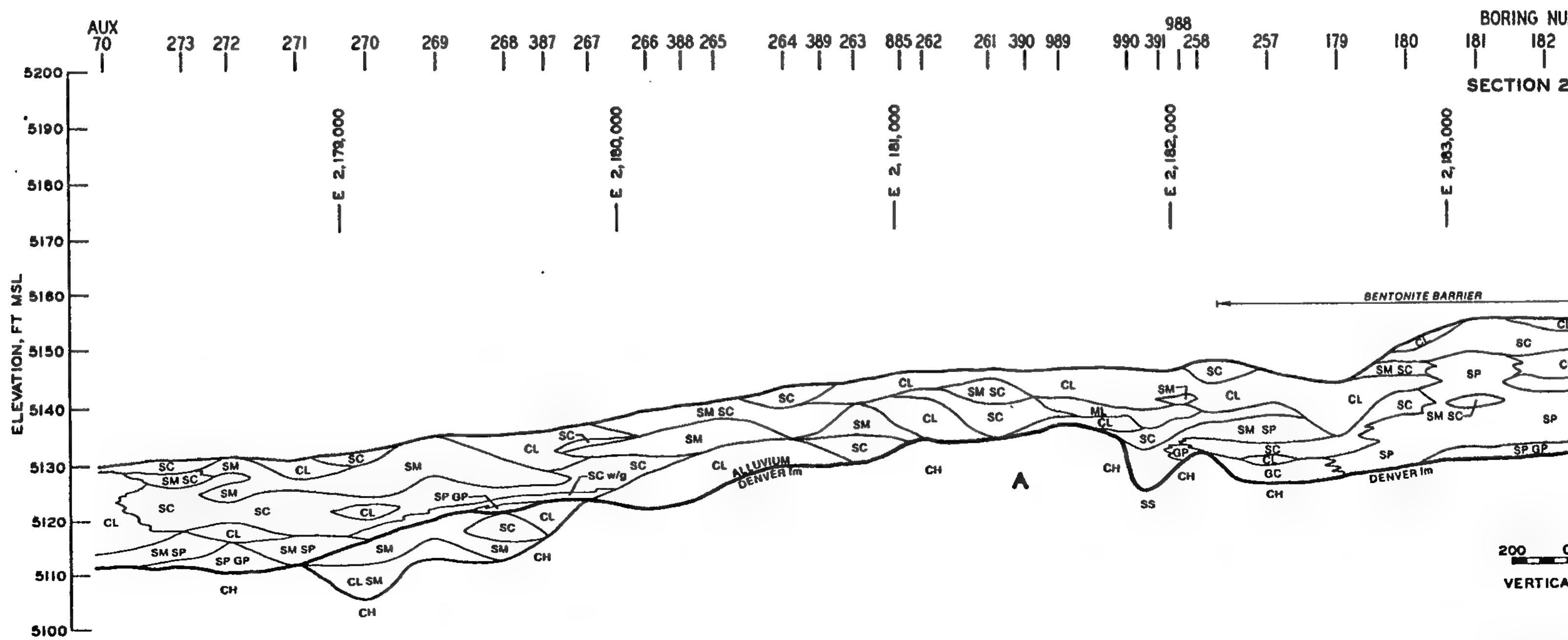
General and Stratigr
with 1959 and



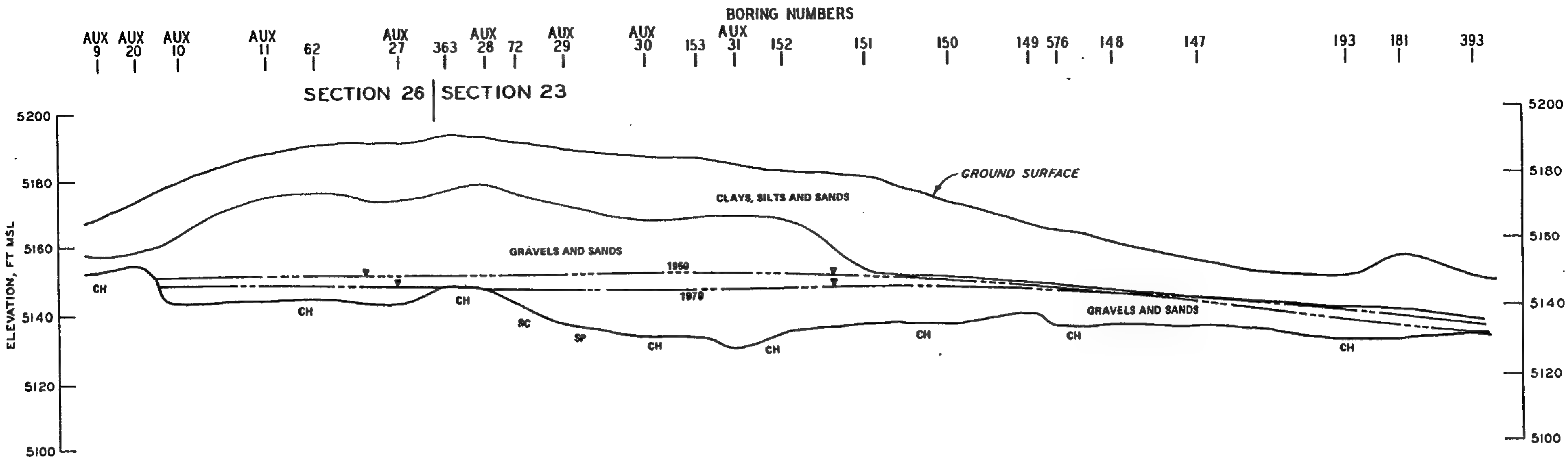
graphic Cross Sections C-C'
1979 Water Levels.

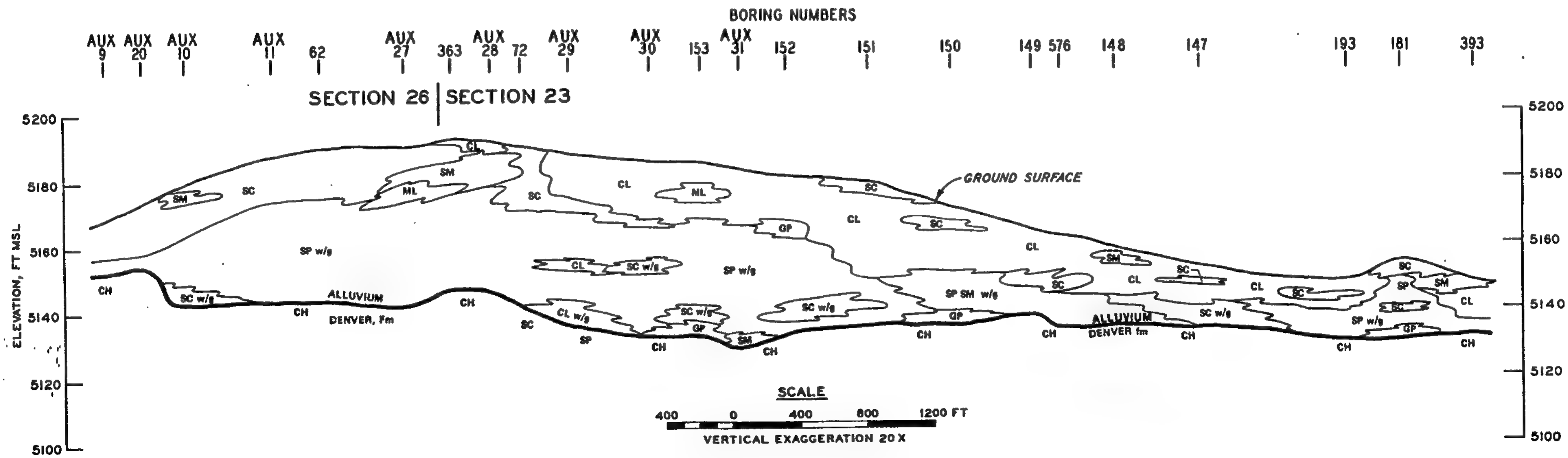
PLATE 3





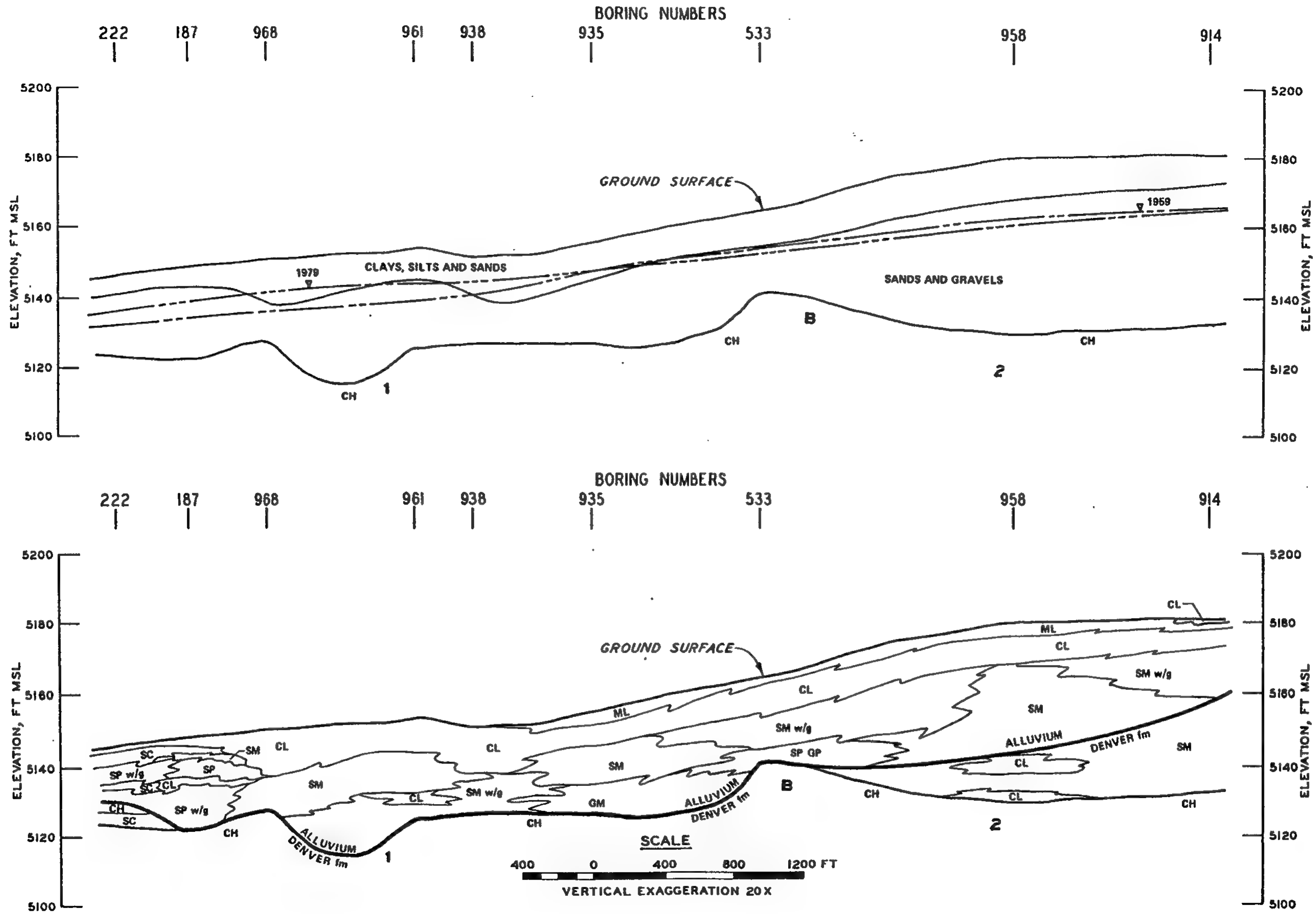
General and Strati
with





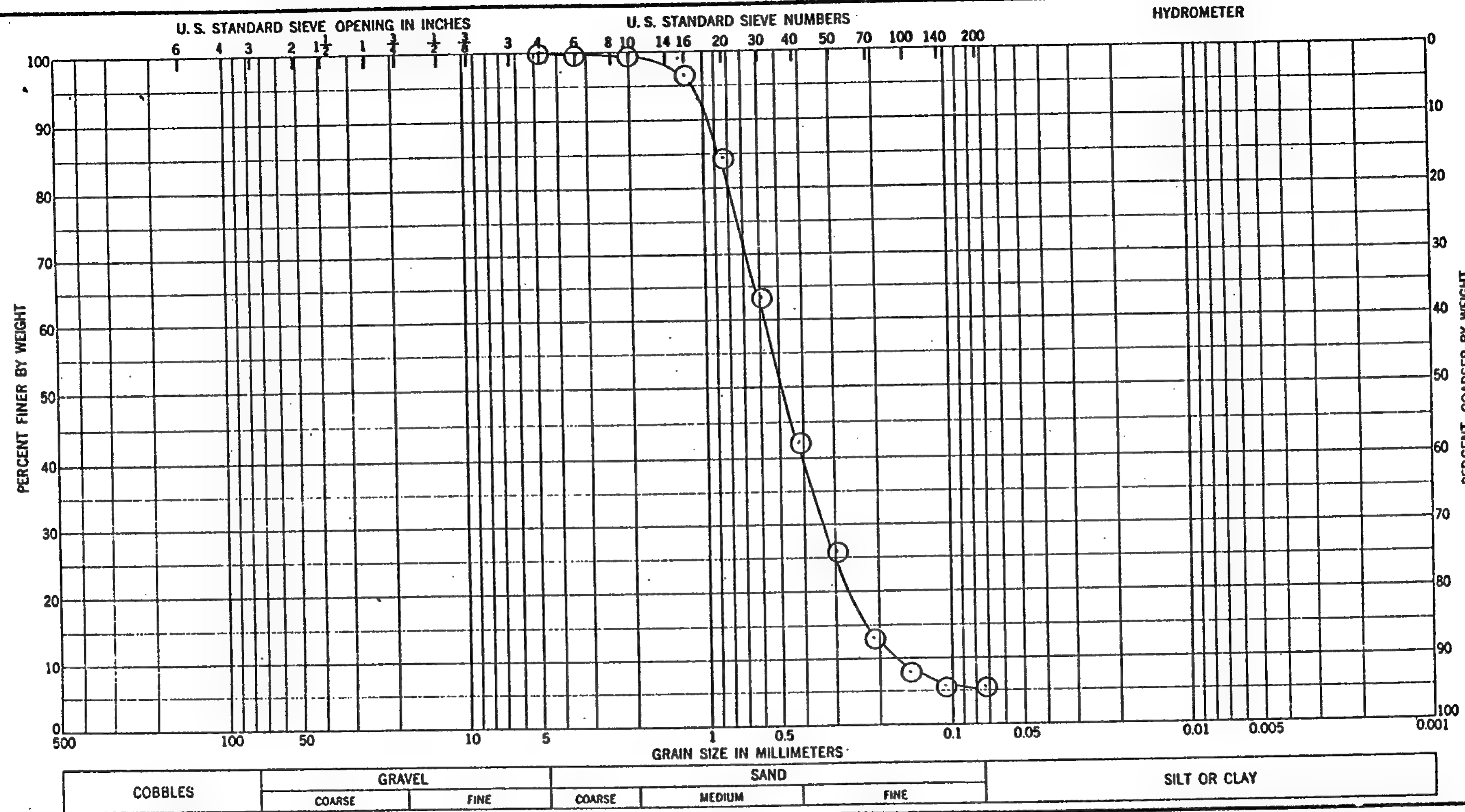
General and Stratigraphic Cross Sections D-D'
with 1959 and 1979 Water Levels.

PLA'



General and Stratigraphic Cross Sections E-E'

APPENDIX A: GRADATION CURVES



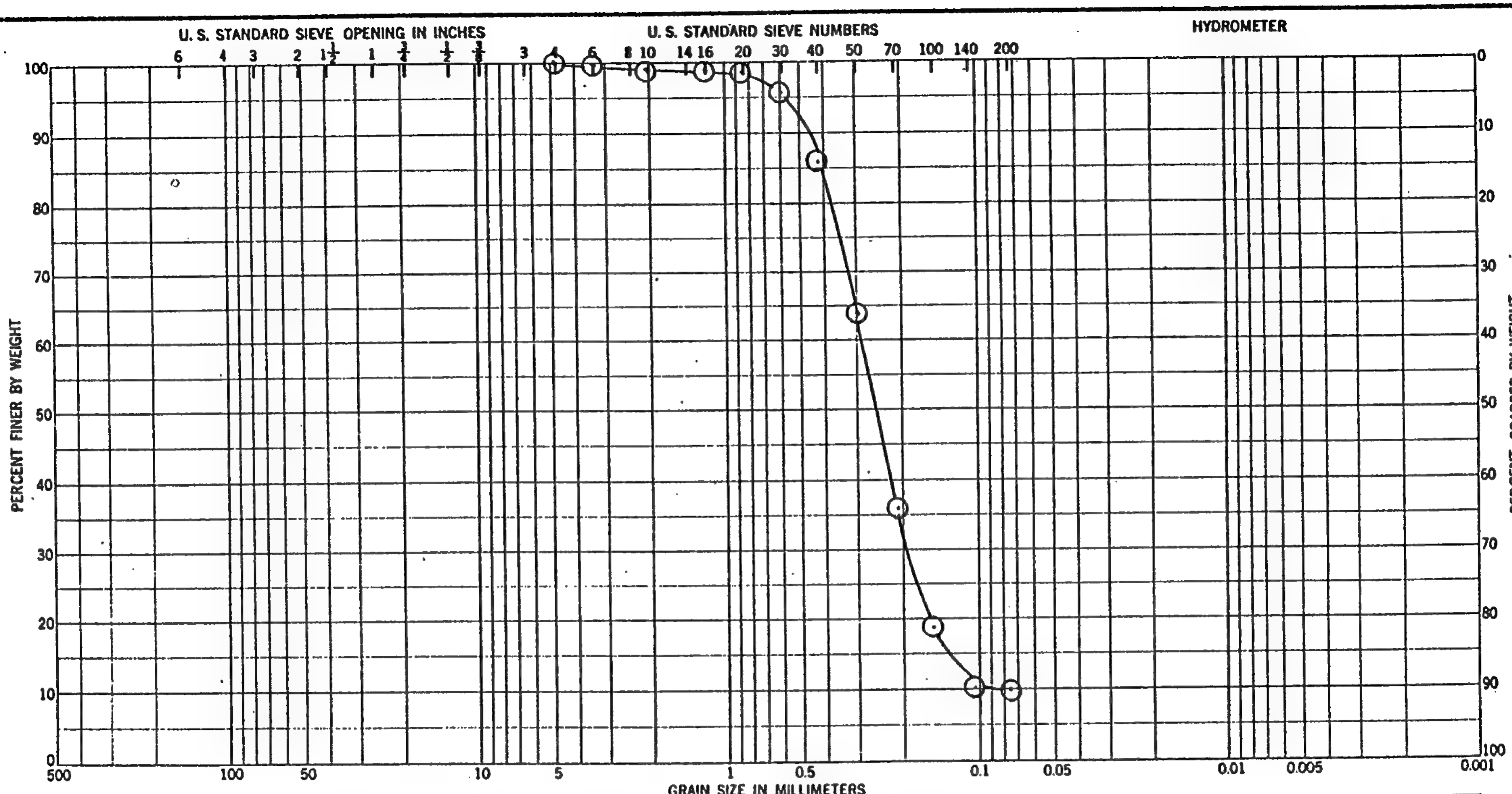
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
3	8.5-9.5	SILTY SAND (SP -SM) BROWN				

GRADATION CURVES

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	347
Date	2 JULY 79

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	13.5-14.5	SILTY SAND (SP-SM) BROWN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 347

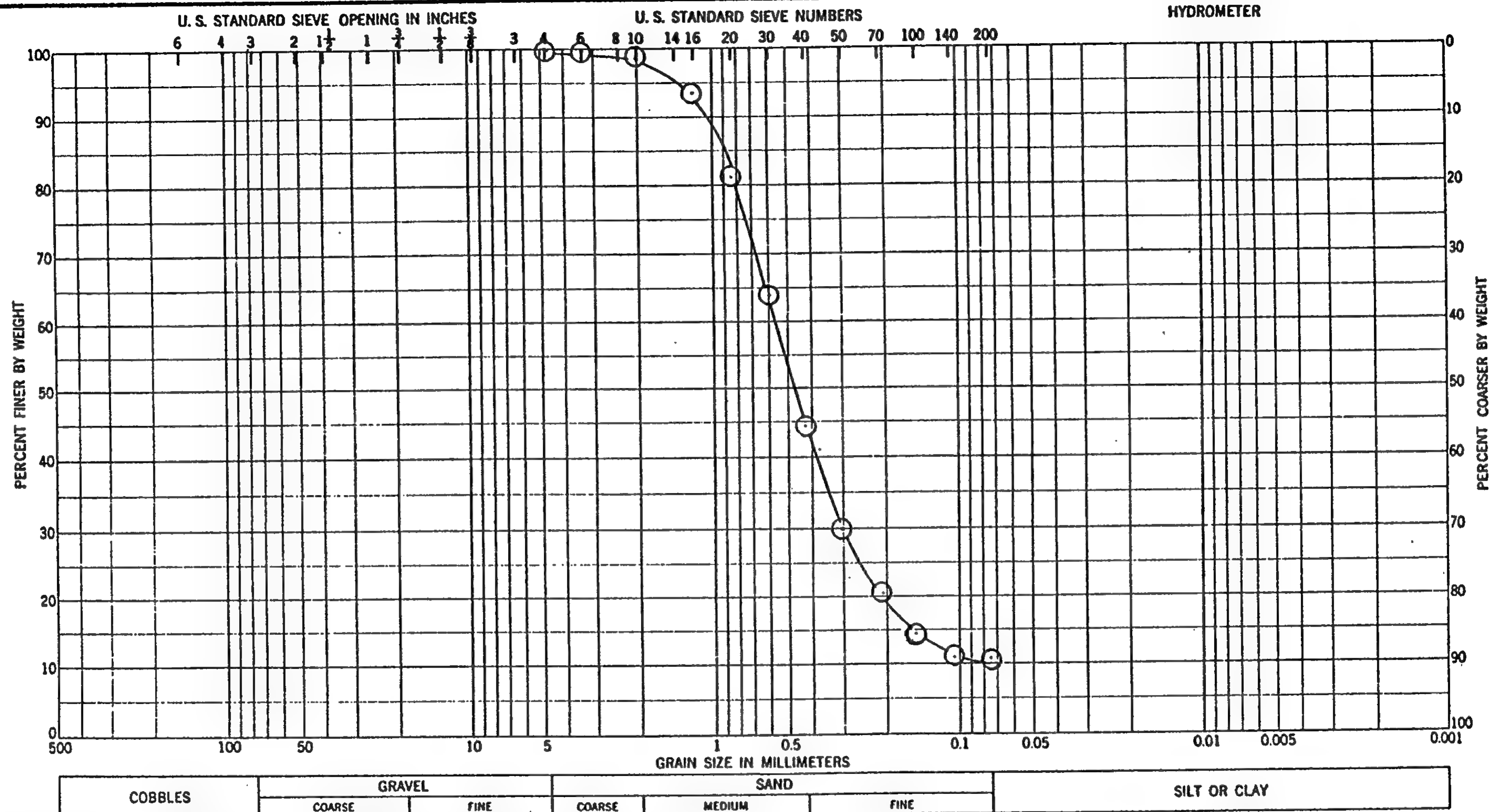
Date 2 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A2



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	18.5-19.5	SILTY SAND (SW-SM) BROWN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No. 347

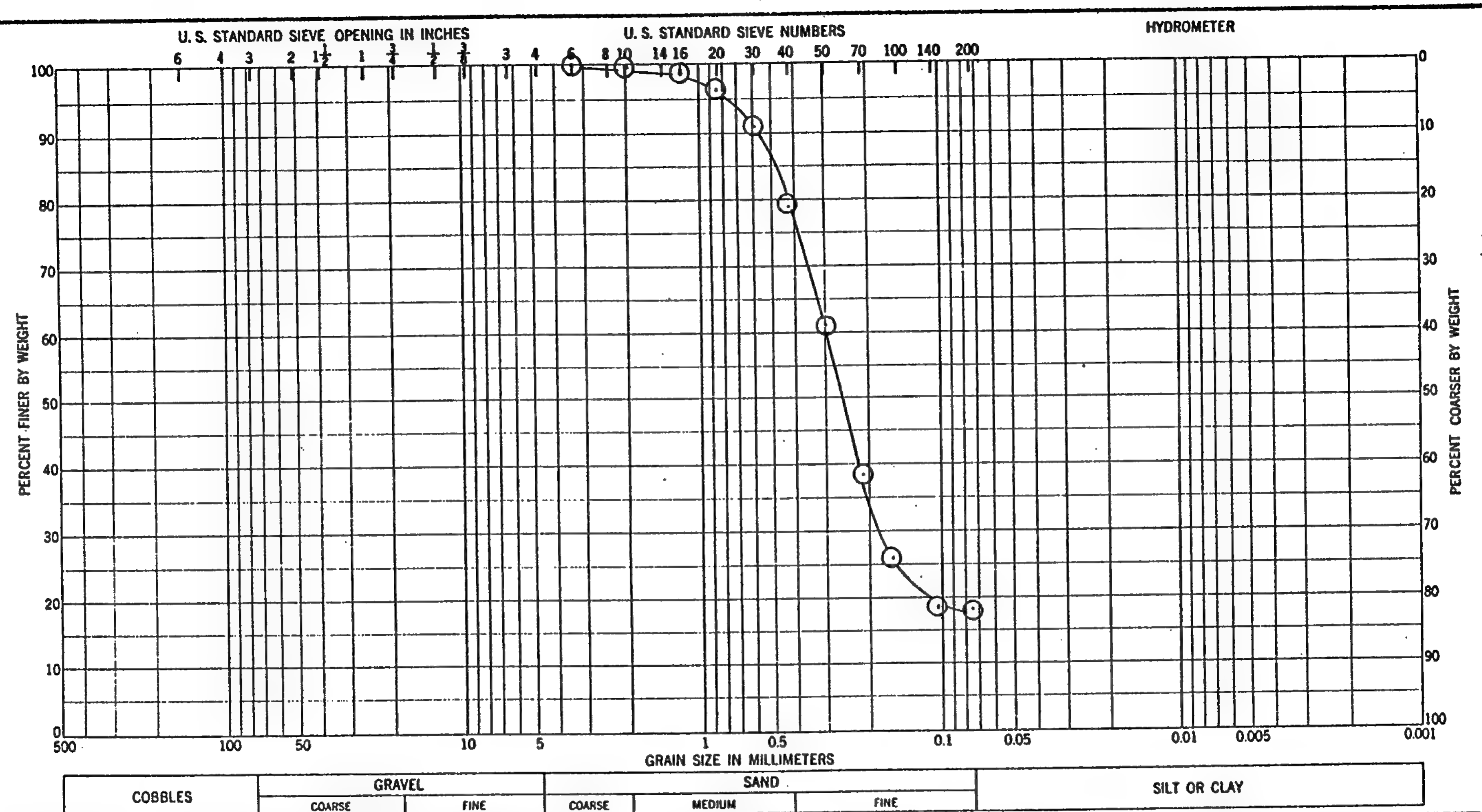
Date: 2 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A3



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	19.0-20.1	CLAYEY SAND (SC) BROWN		35	17	18

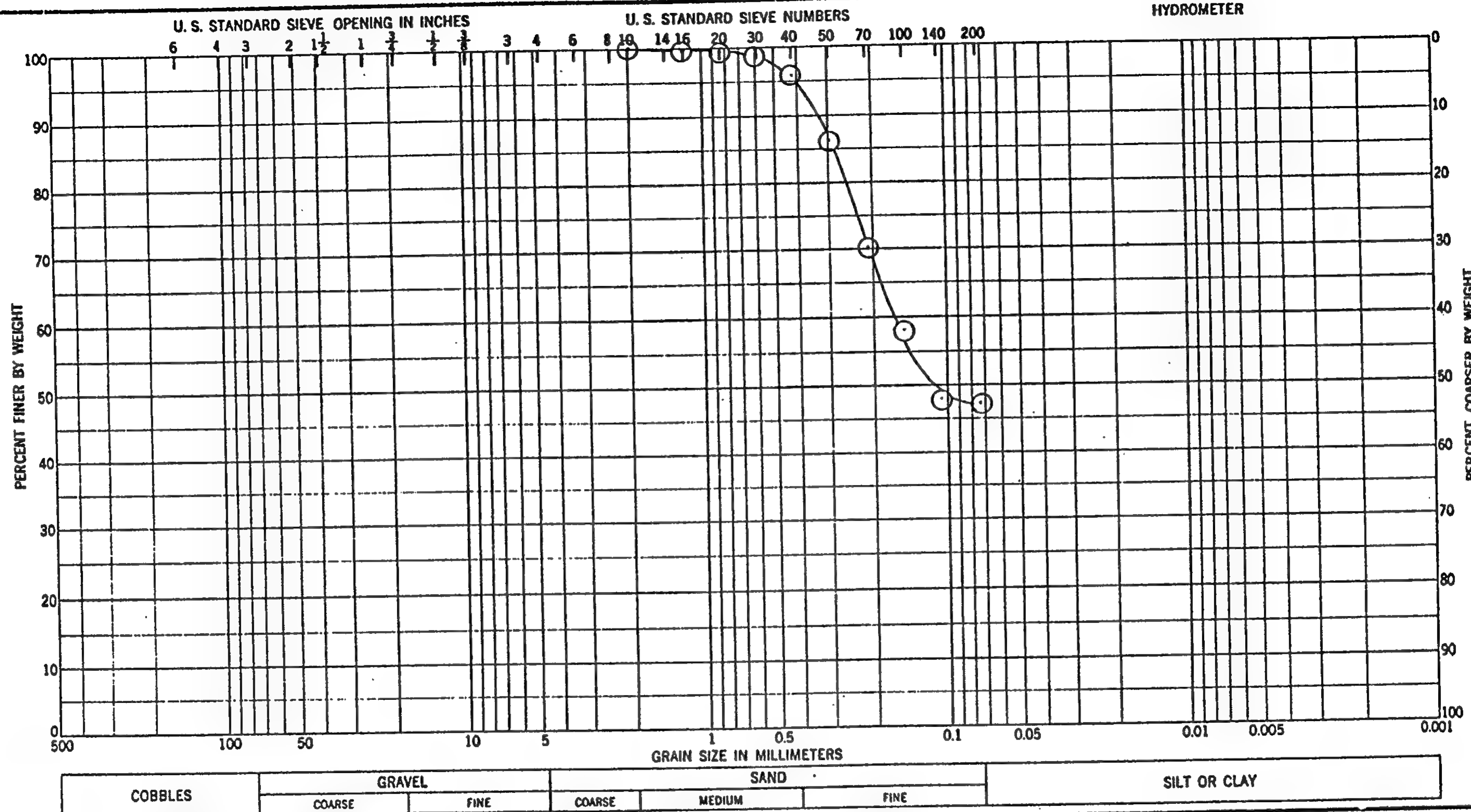
GRADATION CURVES

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	349
Date	3 JULY 79

Plate A4

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
9	38.5-39.5	CLAYEY SAND (SC) BROWN		79	28	51

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No.: 351

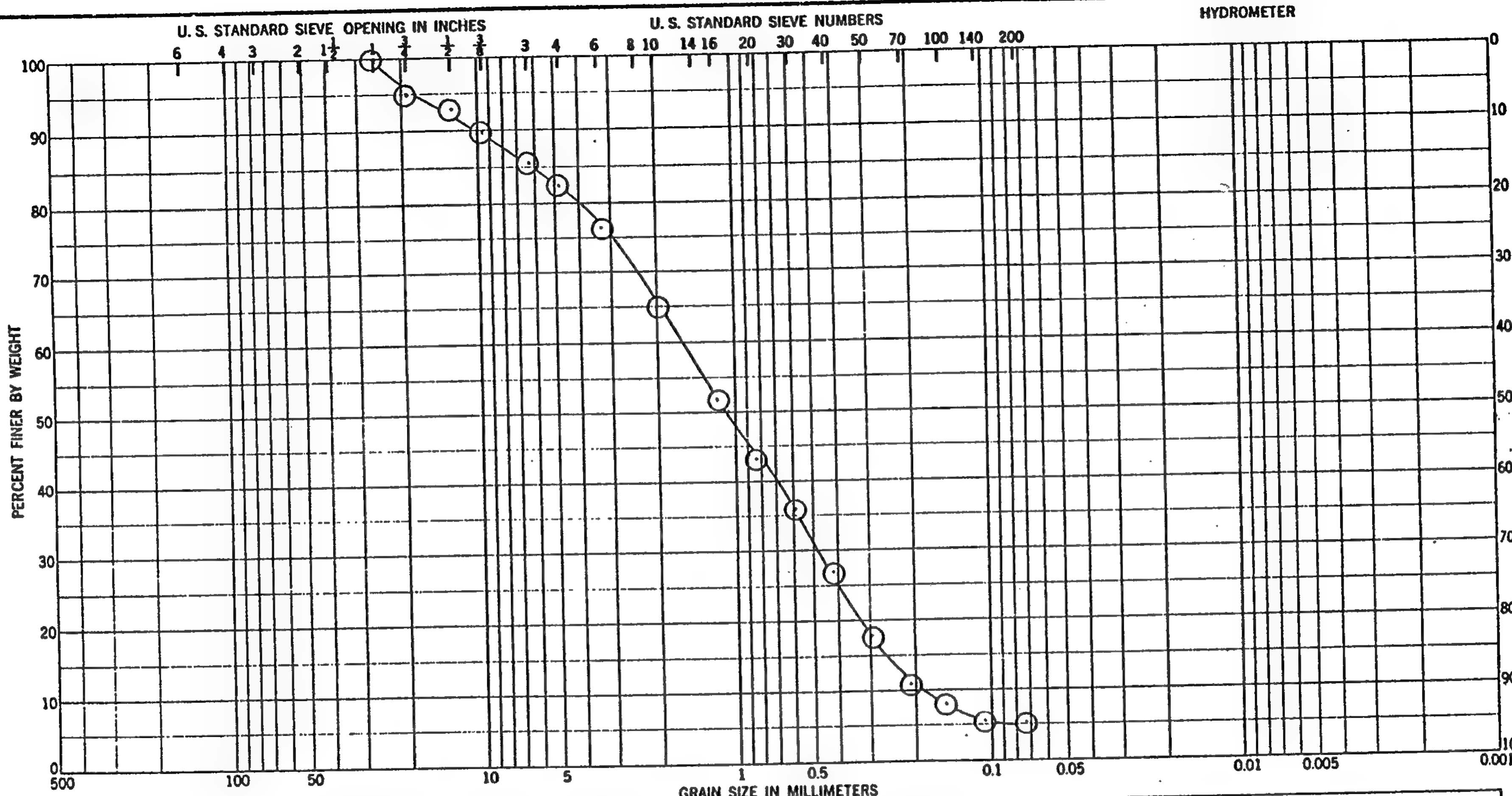
Date: 9 JULY 79

GRADATION CURVES

Plate A5

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	20.0-25.0	GRAVELLY SILTY SAND (SP-SM) TAN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No. 357

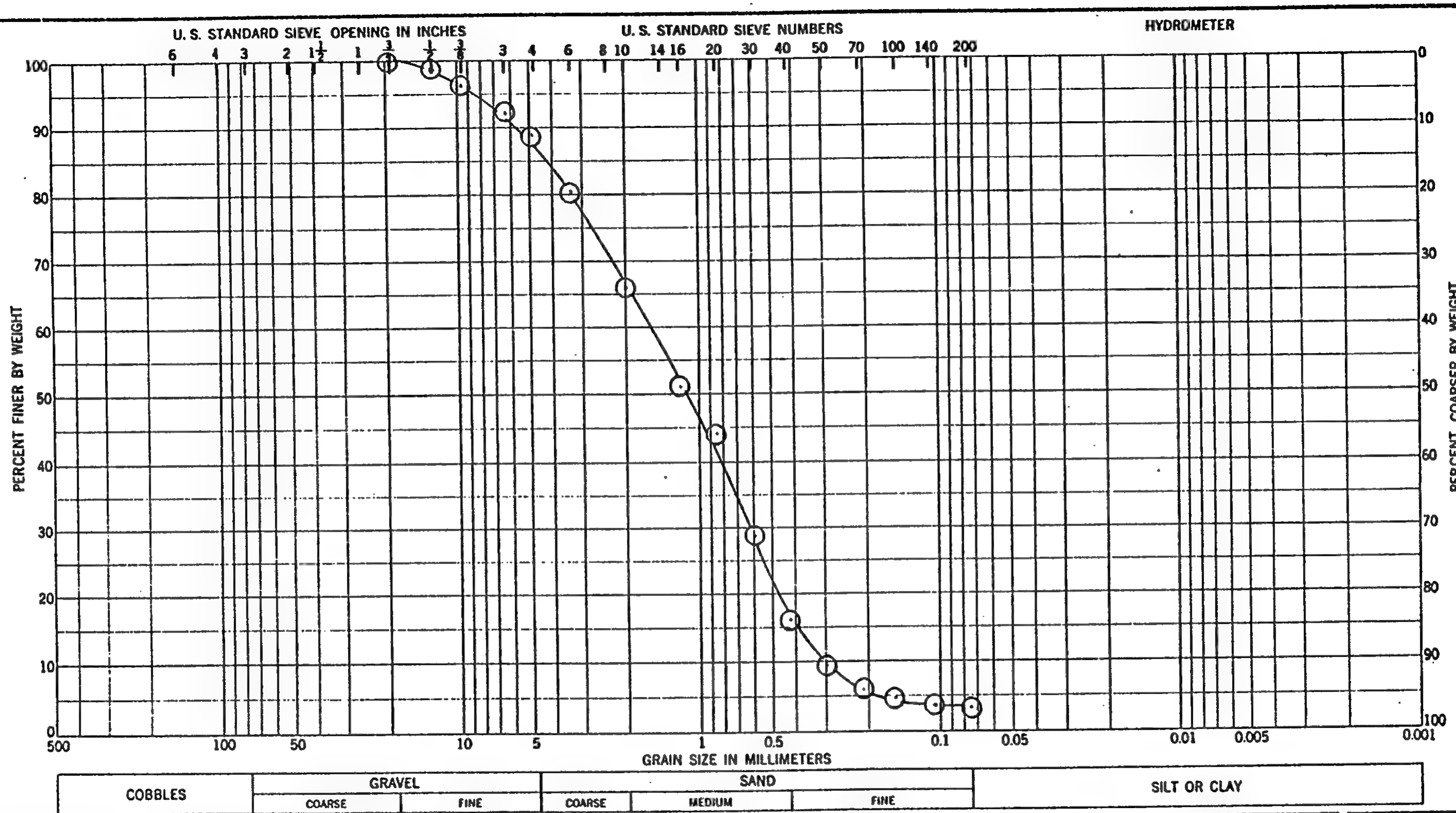
Date 3 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A6



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	25.0-27.0	SAND (SP) WITH GRAVEL				
		BROWN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 358

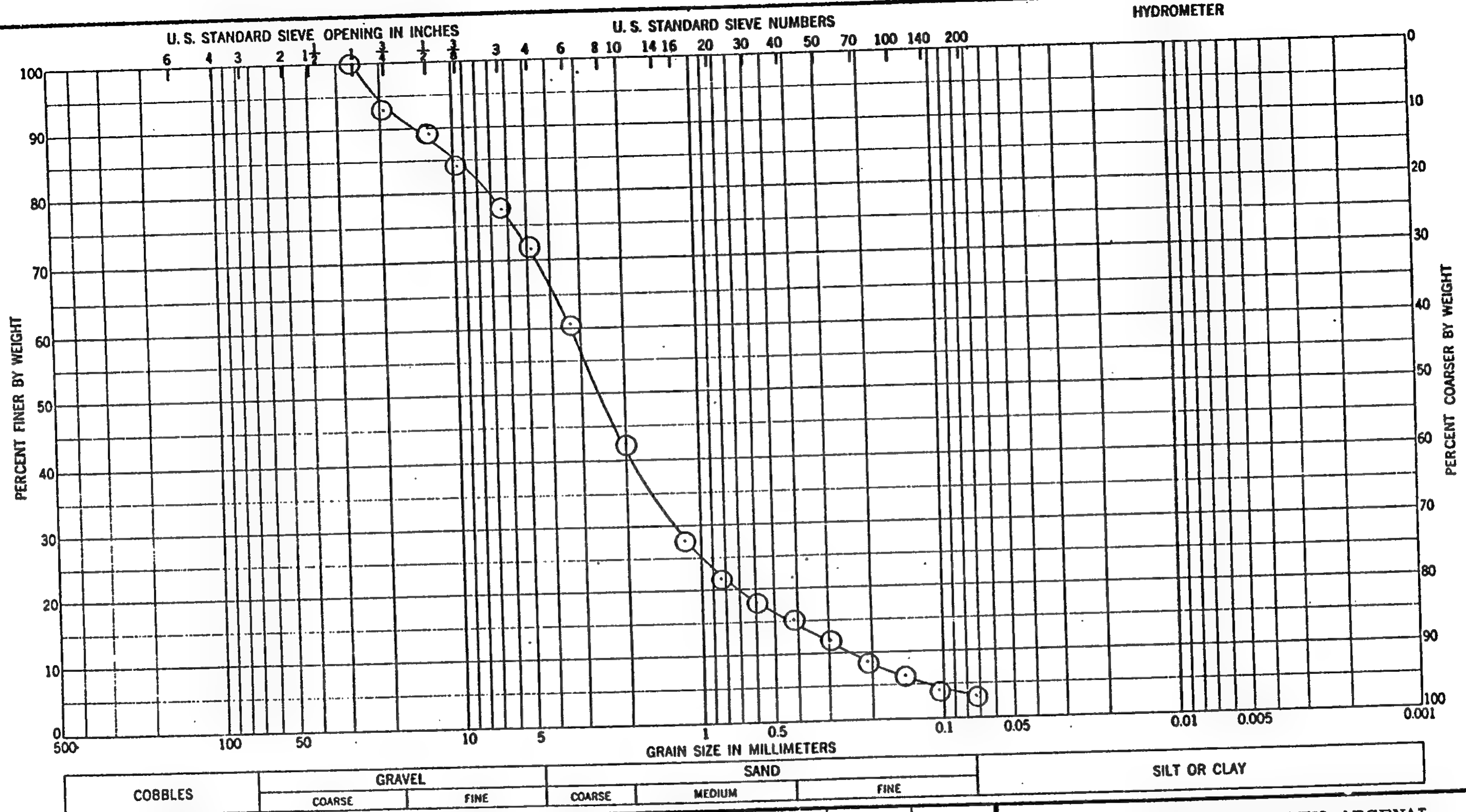
Date 2 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A7



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
9	35.0-37.0	GRAVELLY SAND (SW) BROWN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No.: 359

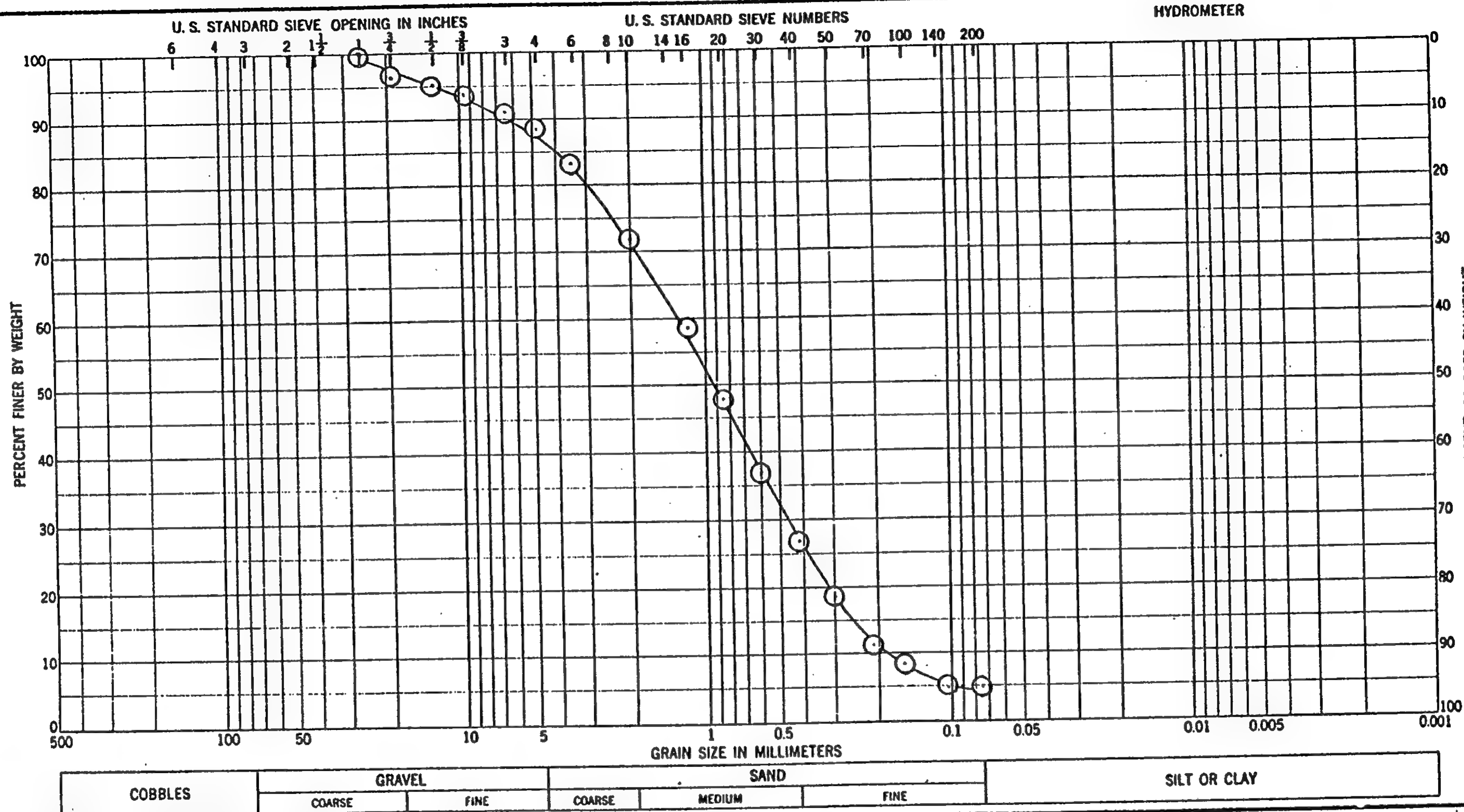
Date: 3 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A8



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
11	40.0-42.0	Sand (SP) with Gravel Tan				

Project Rocky Mountain Arsenal

Area

Boring No. 362

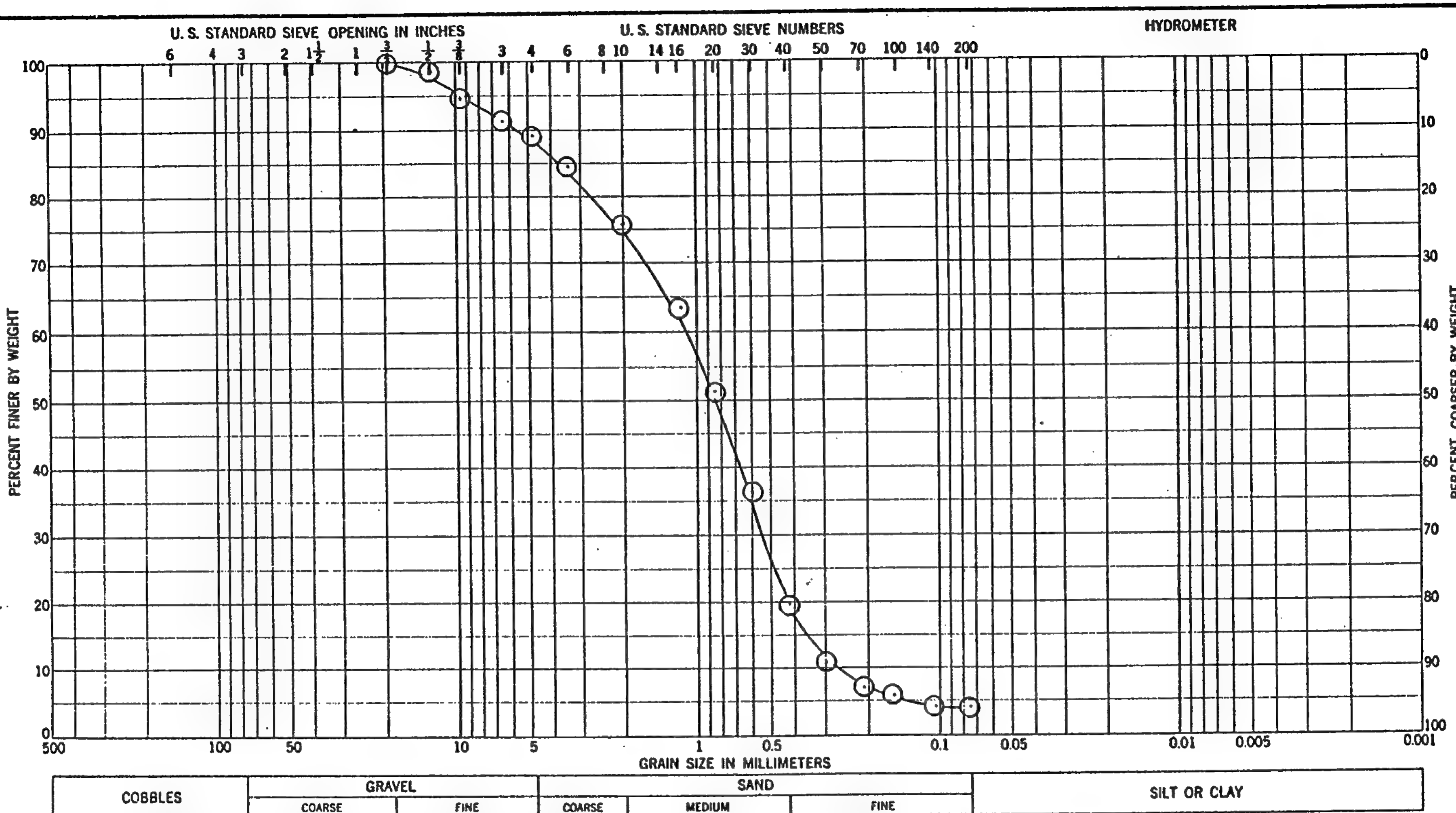
Date 2 July 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A9



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
11	45.0-50.0	SAND (SP) WITH GRAVEL BROWN				

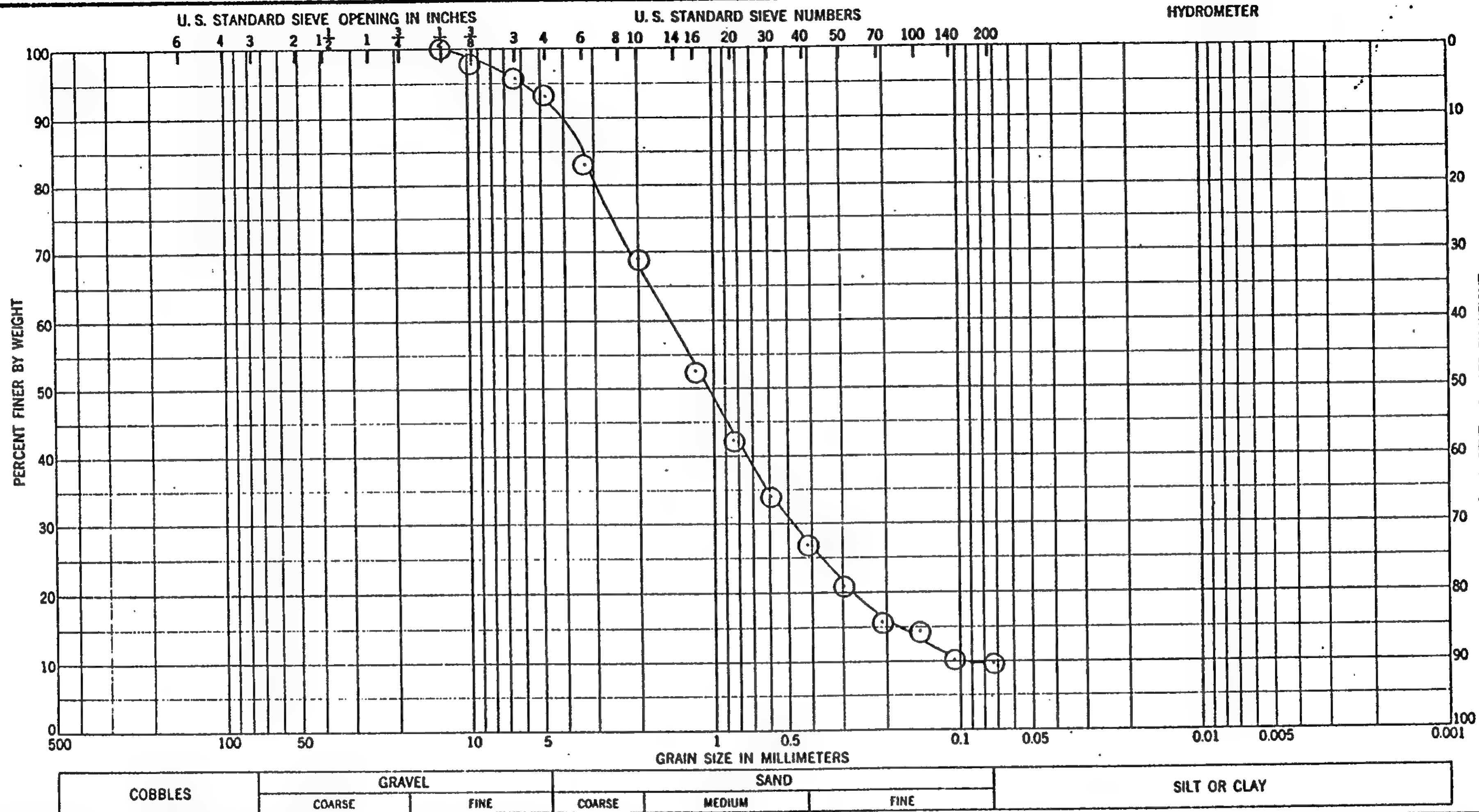
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	363
Date	2 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A10



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
14	43.0-44.2	SILTY SAND (SW-SM) WITH GRAVEL TAN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No. 364

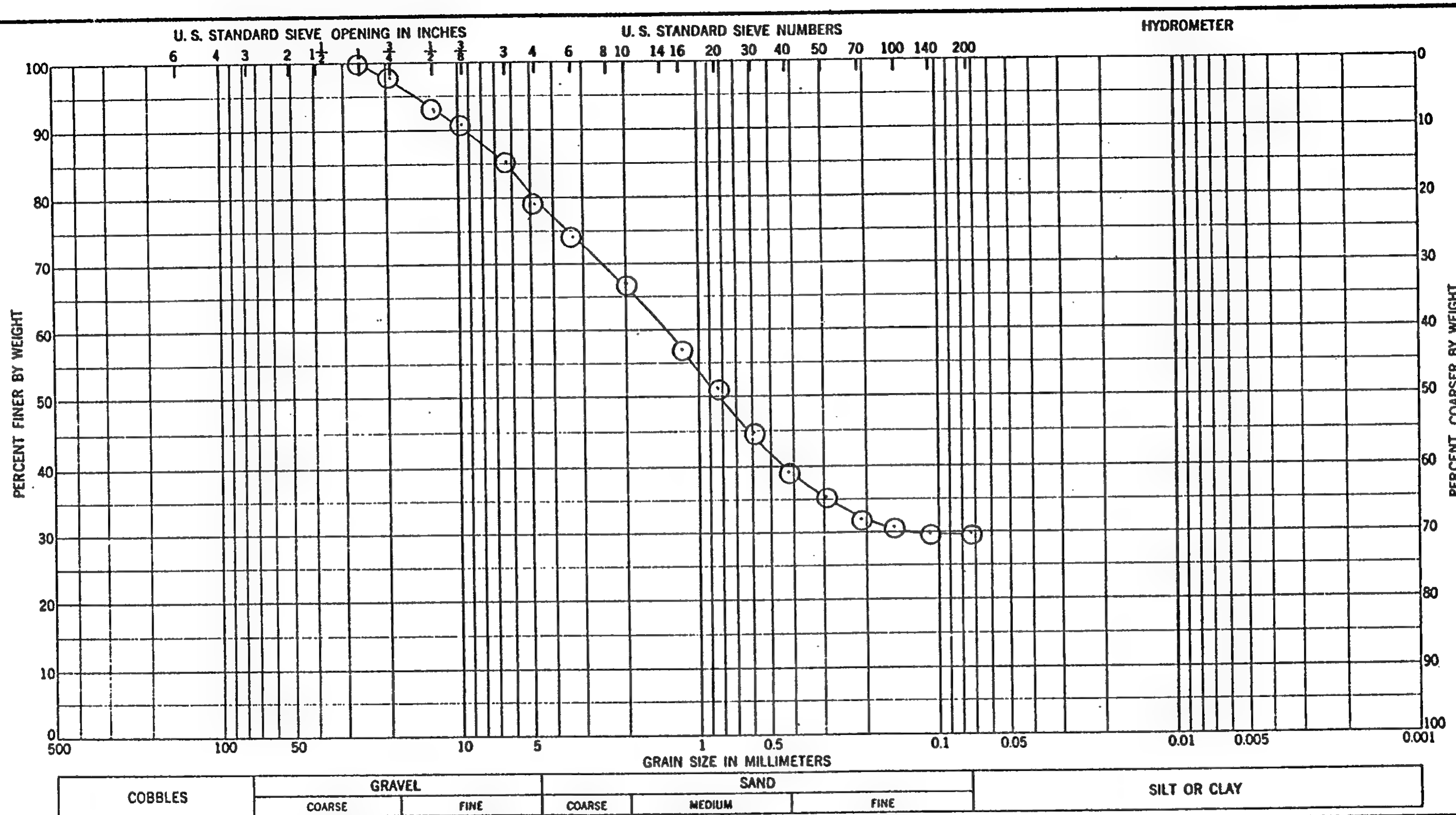
Date: 11 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A11



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
12	40.0-40.8	GRAVELLY SILTY SAND (SM) BROWN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No.: 366

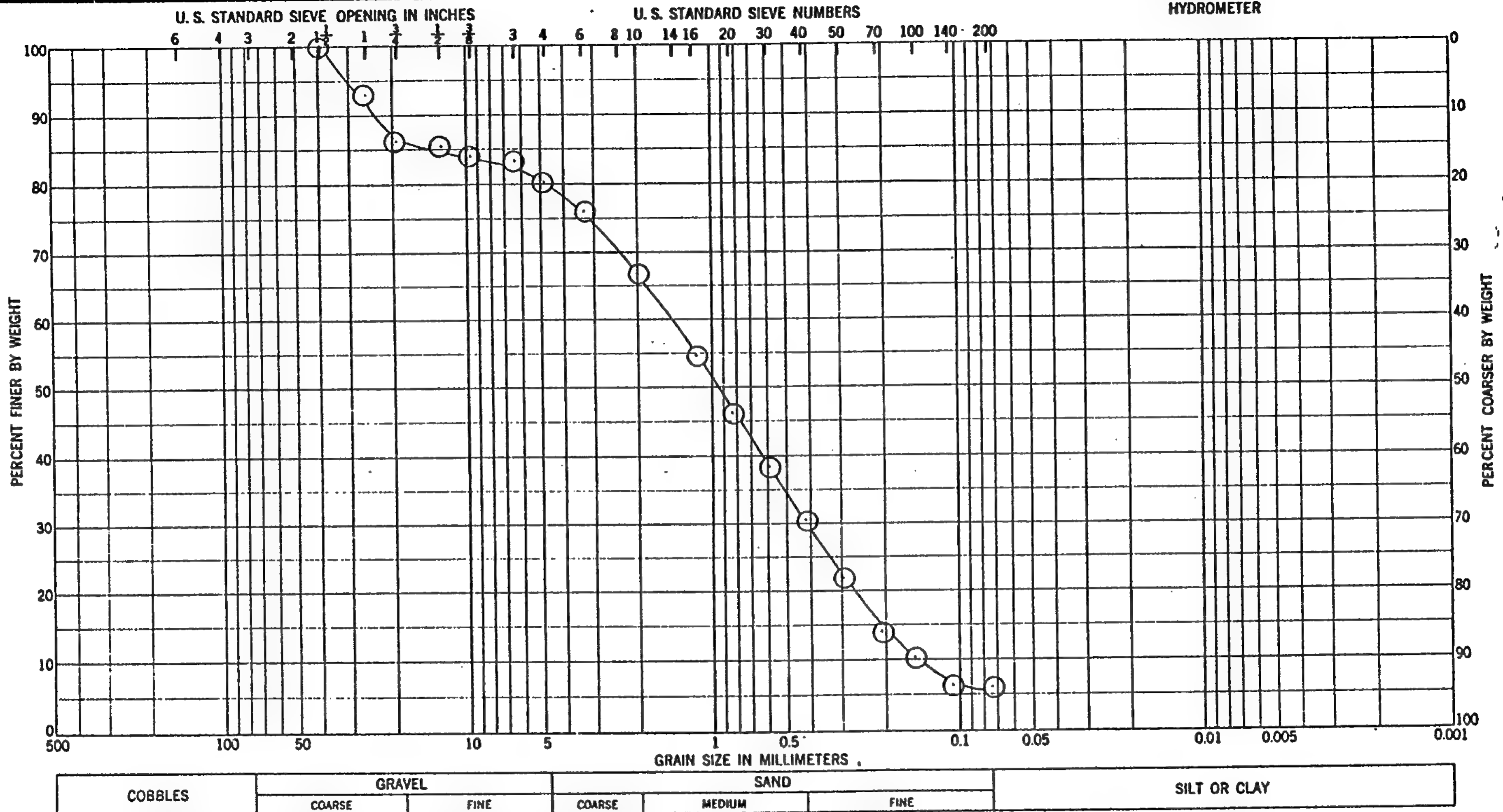
Date: 2 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A12



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
10	43.0-44.5	GRAVELLY SILTY SAND (SP-SM) TAN				

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

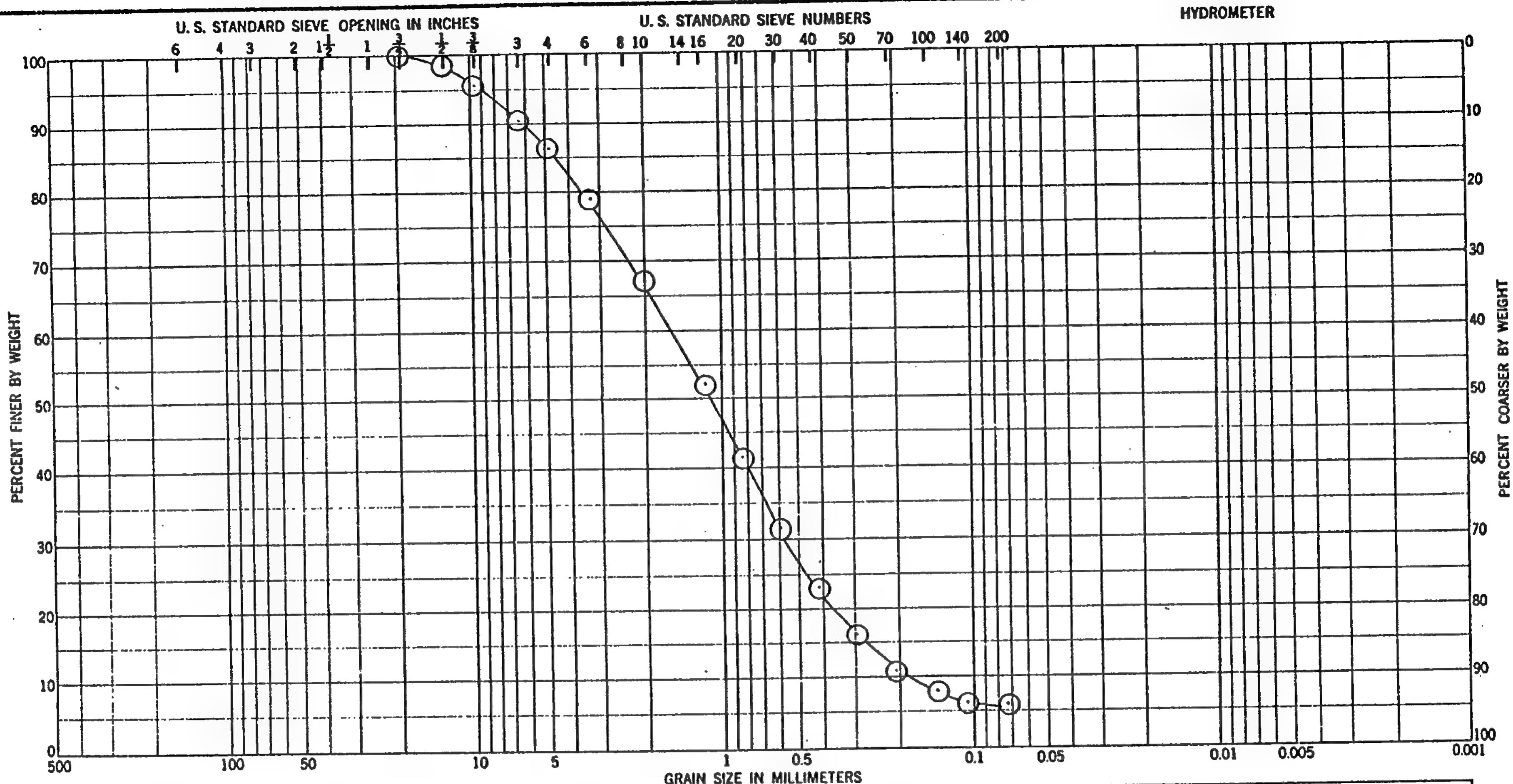
Area

Boring No. 378

Date 3 JULY 79

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

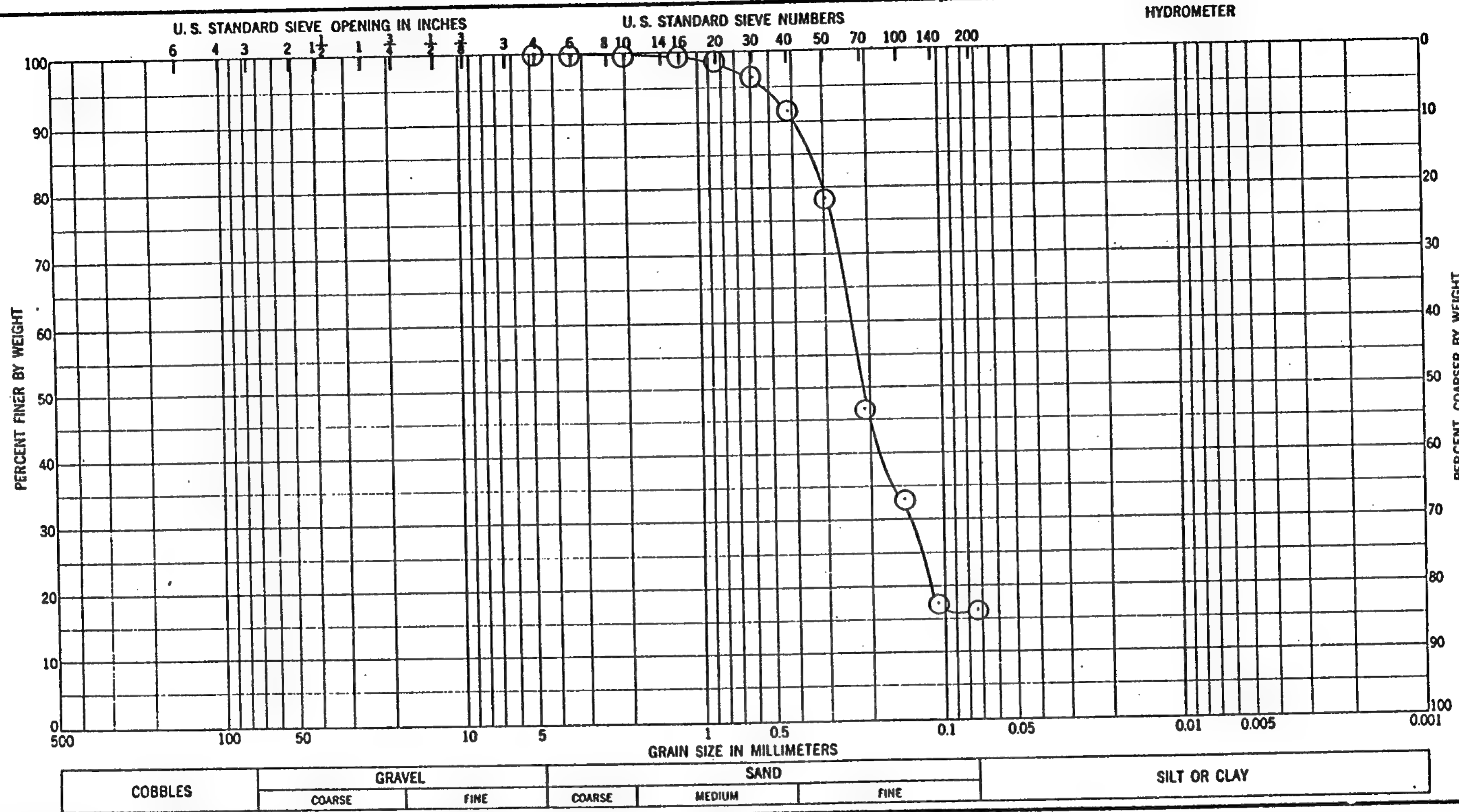
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6 & 7	24.0-25.5;	GRAVELLY SILTY SAND (SW-SM)				
	29.0-30.5	TAN				

GRADATION CURVES

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	379
Date	11 JULY 79

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	SILTY SAND (SM) TAN				

Project: ROCKY MOUNTAIN ARSENAL

Area

Boring No. 380

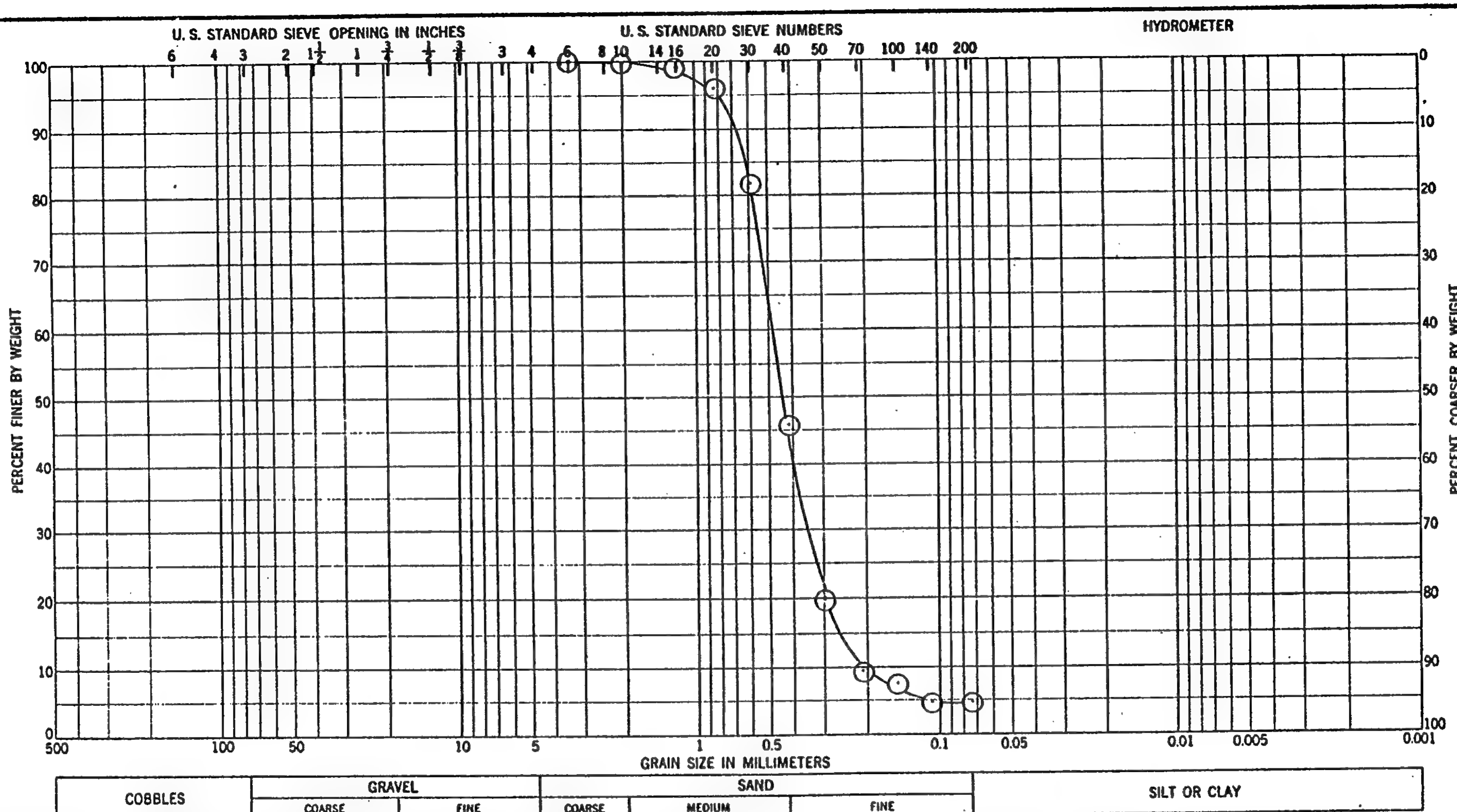
Date 3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A15



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
9	39.0-40.5	SAND (SP) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 385

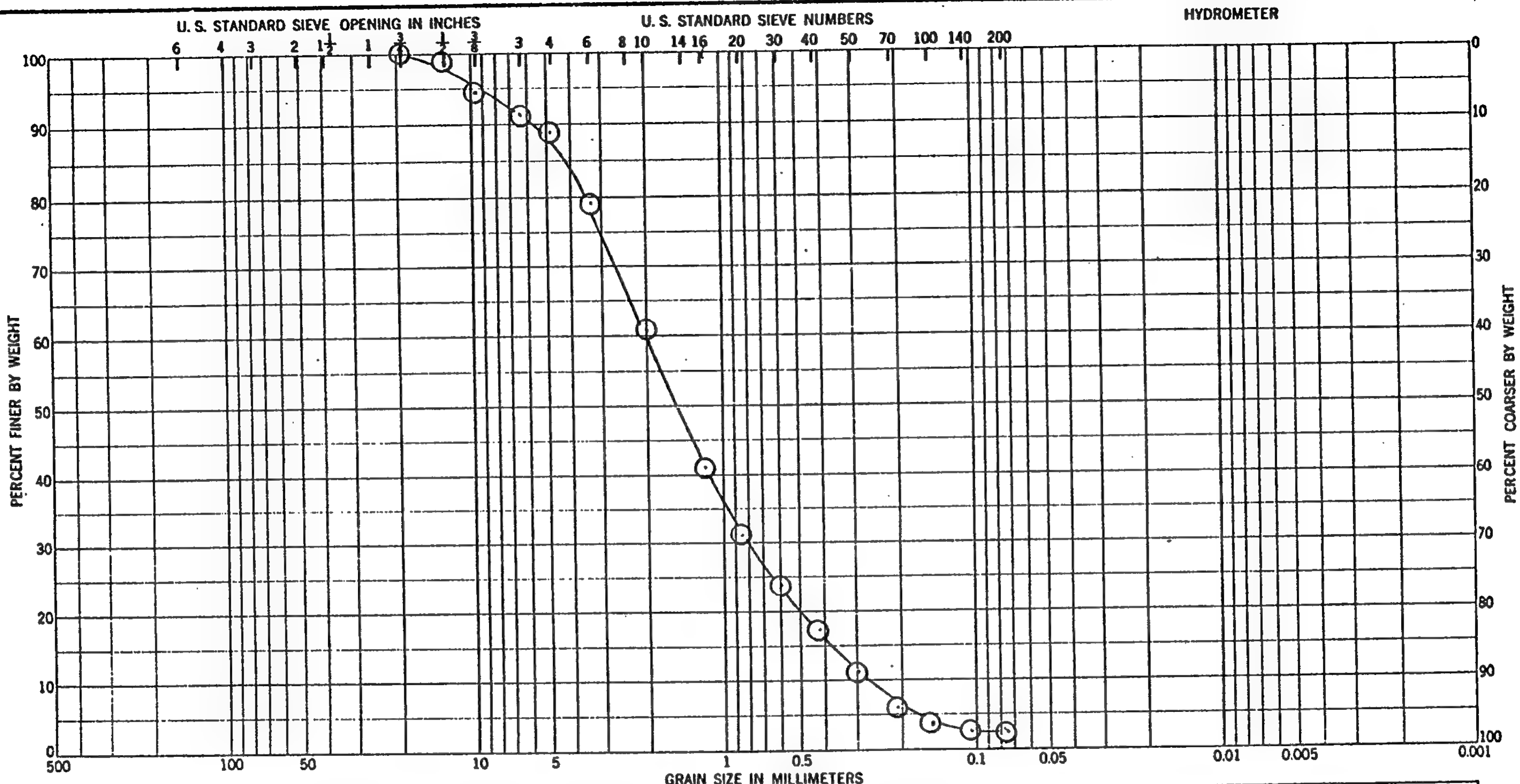
Date 2 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A16



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
11	29.5-30.5	SAND (SW) WITH GRAVEL BROWN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 529

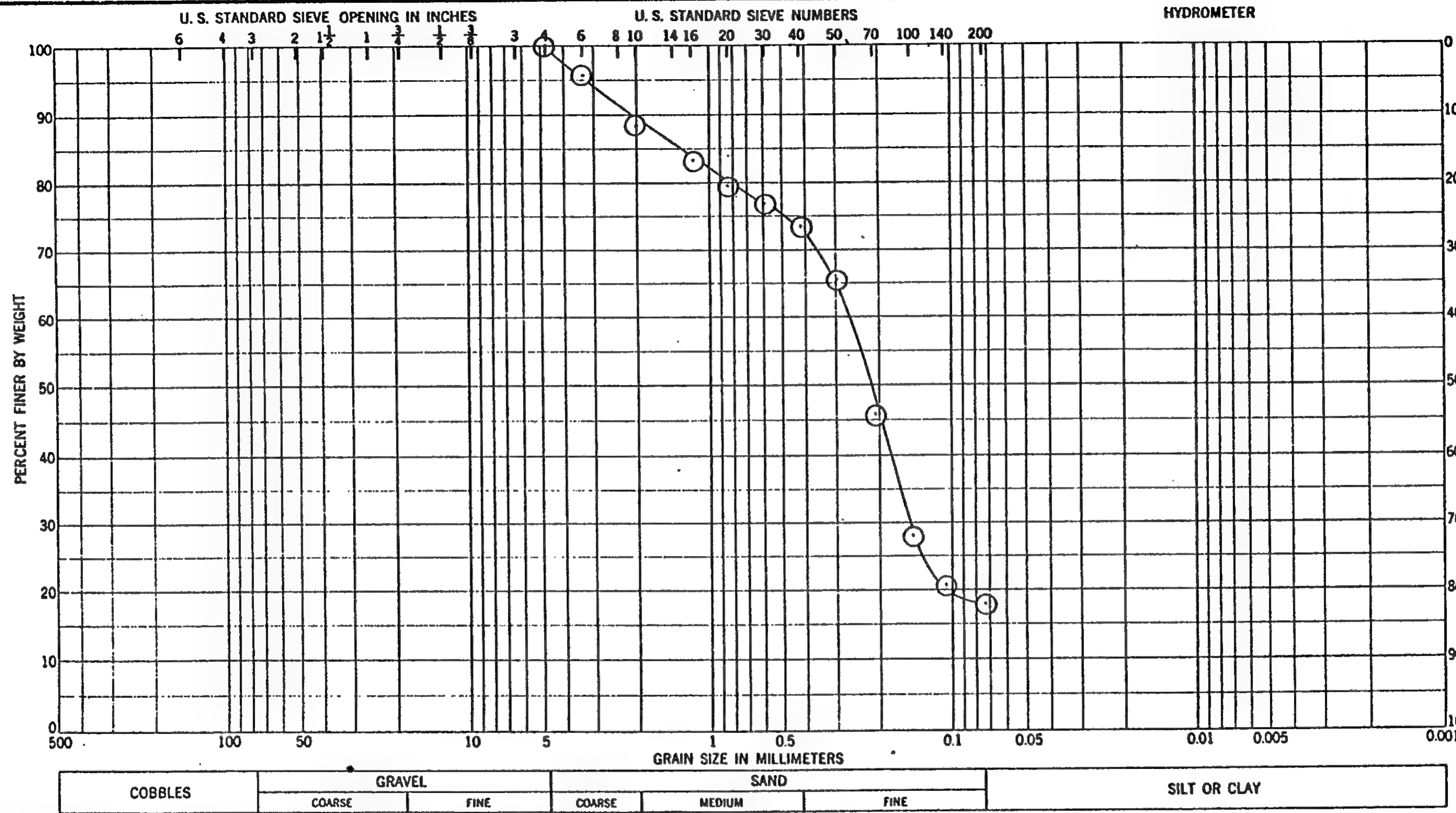
Date 2 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A17

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	19.0-20.5	SILTY SAND (SM) TAN				

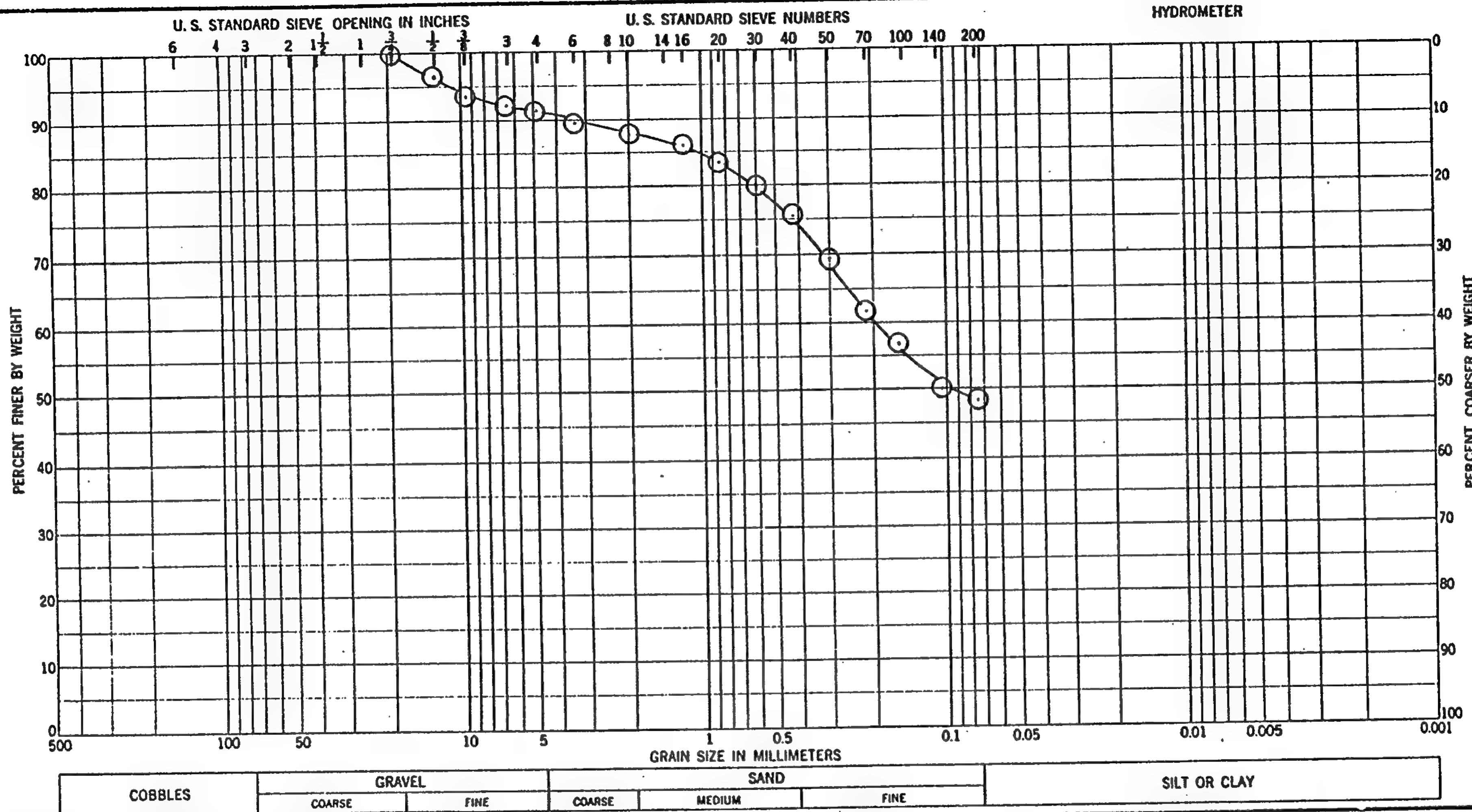
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	532
Date	11 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A18



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	24.0-25.5	SILTY SAND (SM) WITH GRAVEL BROWN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 532

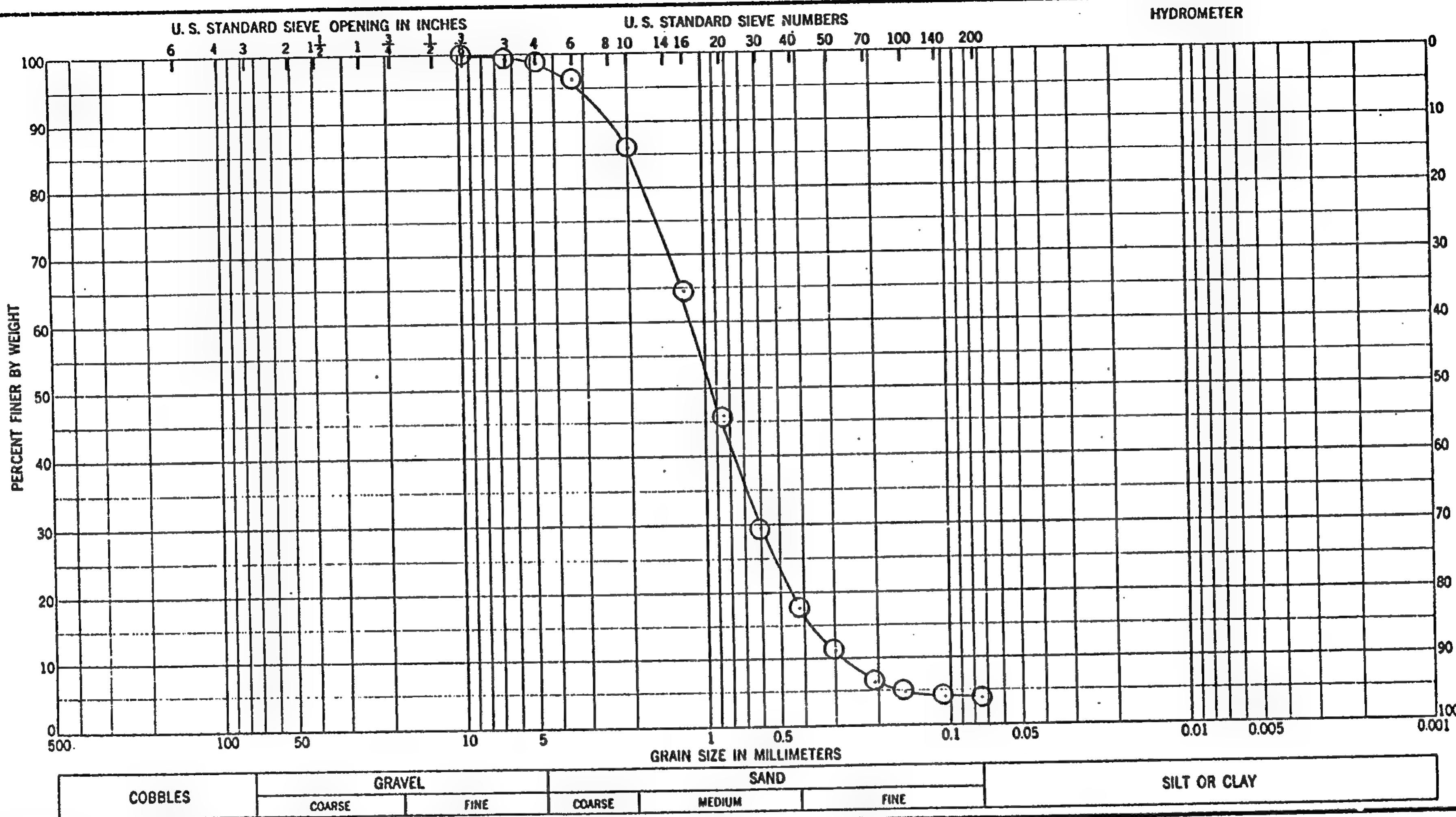
Date 3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A19



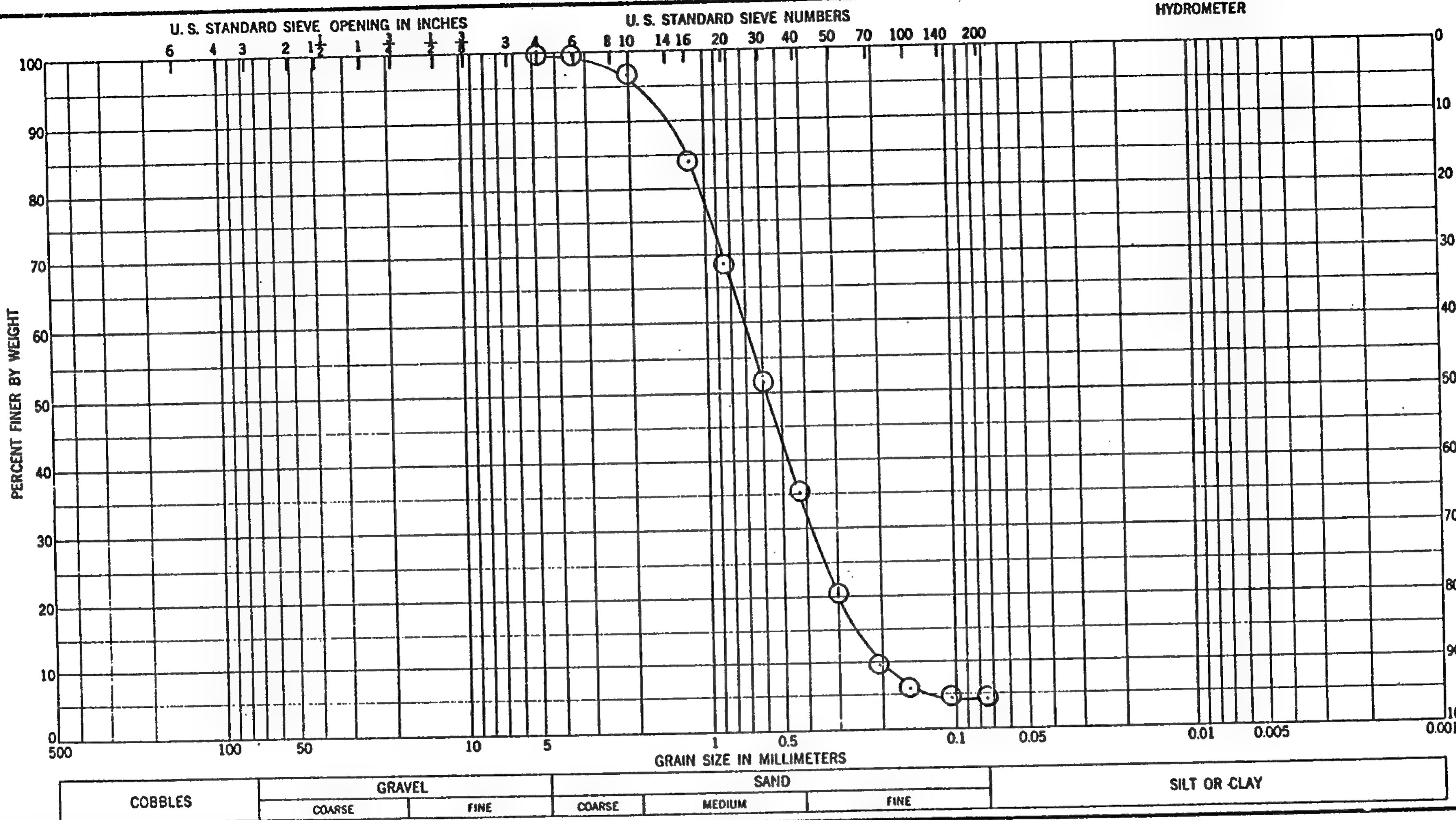
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	23.5-24.2	SAND (SP) TAN				

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	548
Date	11 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	24.0-25.2	Sand (SP) Brown				

Project Rocky Mountain Arsenal

Area

Boring No. 570

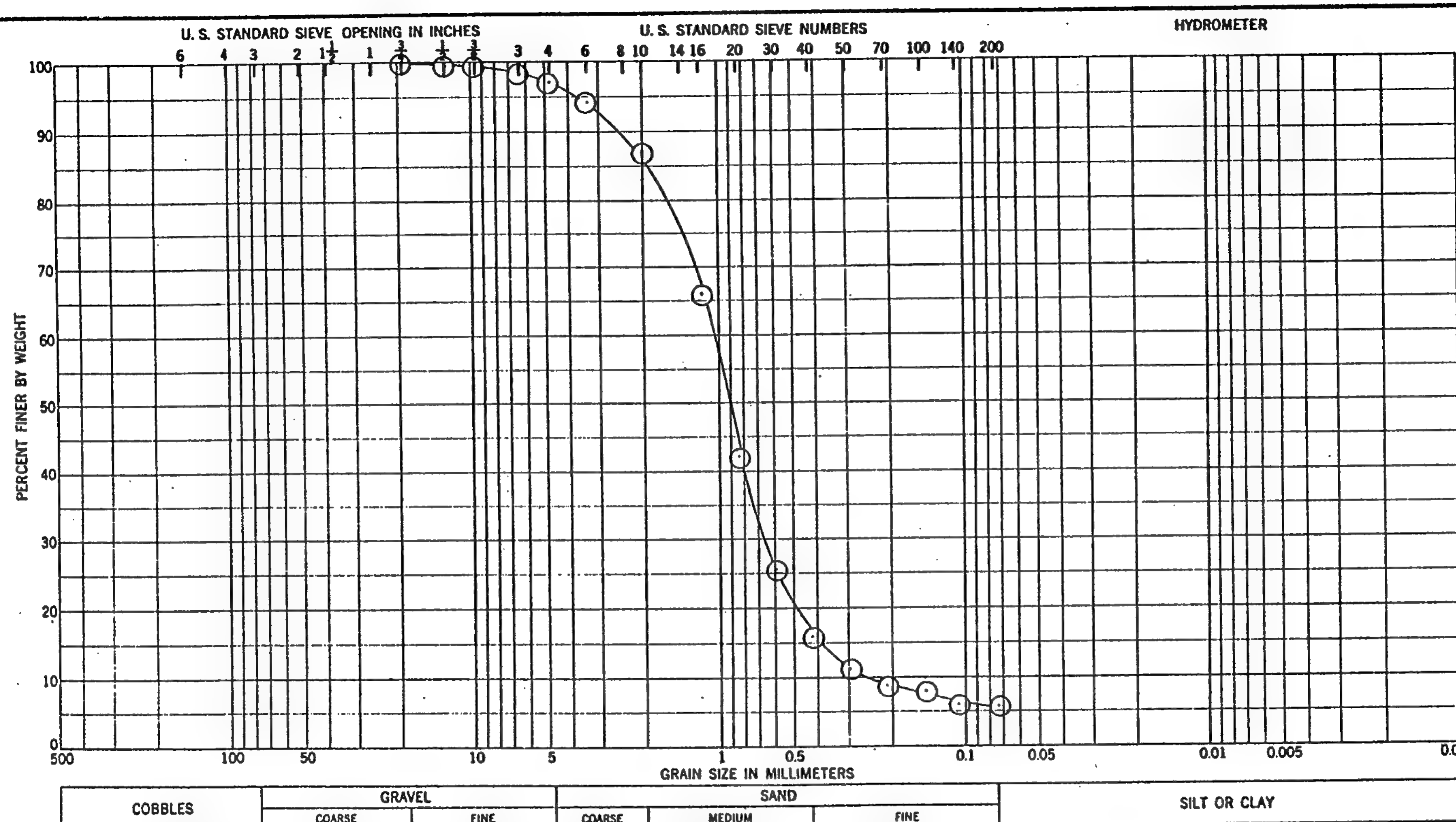
Date 2 July 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A21



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	28.4-30.6	SILTY SAND (SP-SM) BROWN				

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

Area

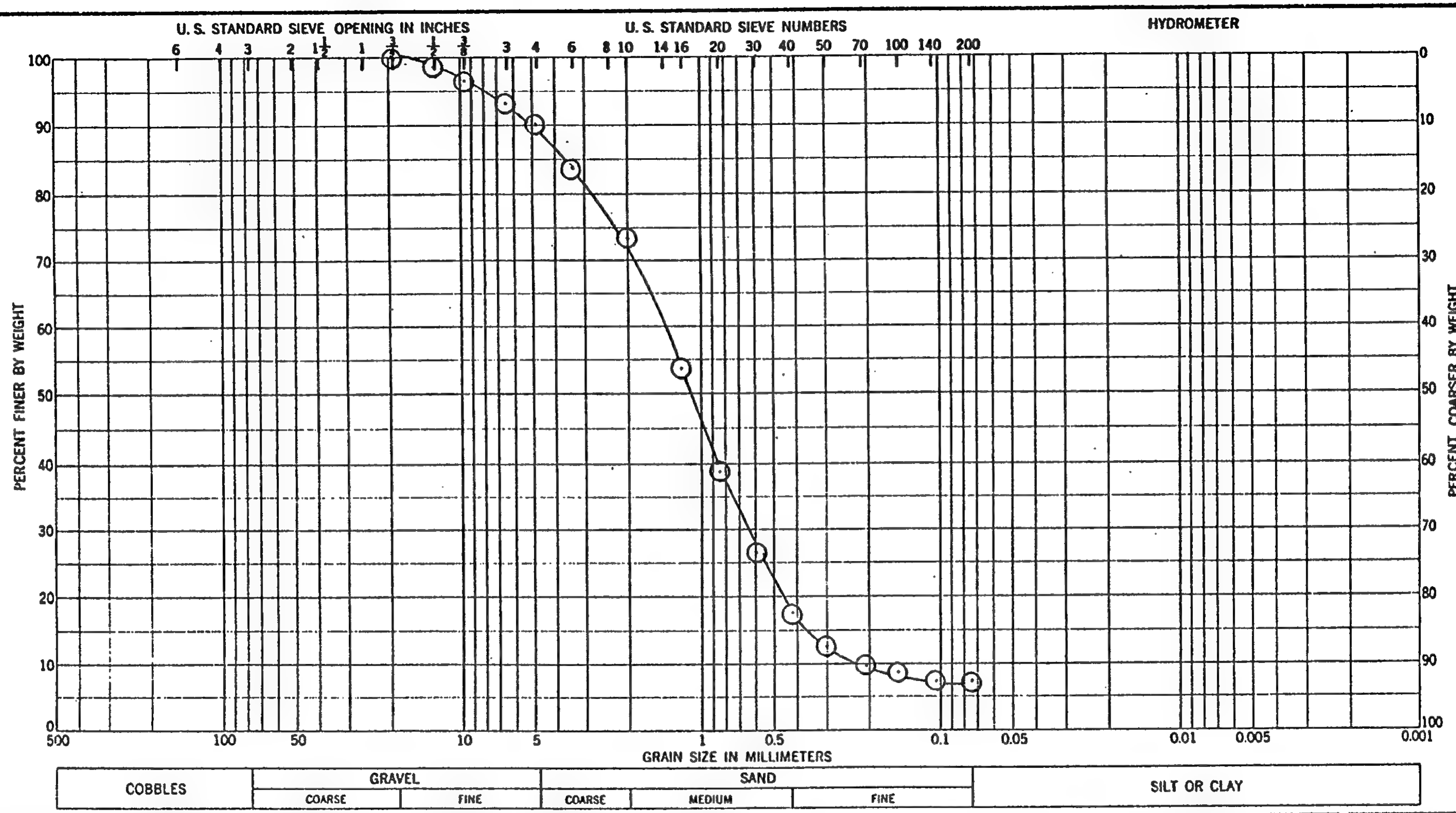
Boring No. 571

Date 3 JULY 79

Results of Sieve Analysis

Plate A22

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	23.5-24.7	SILTY SAND (SW - SM) WITH GRAVEL BROWN				

GRADATION CURVES

Project: ROCKY MOUNTAIN ARSENAL

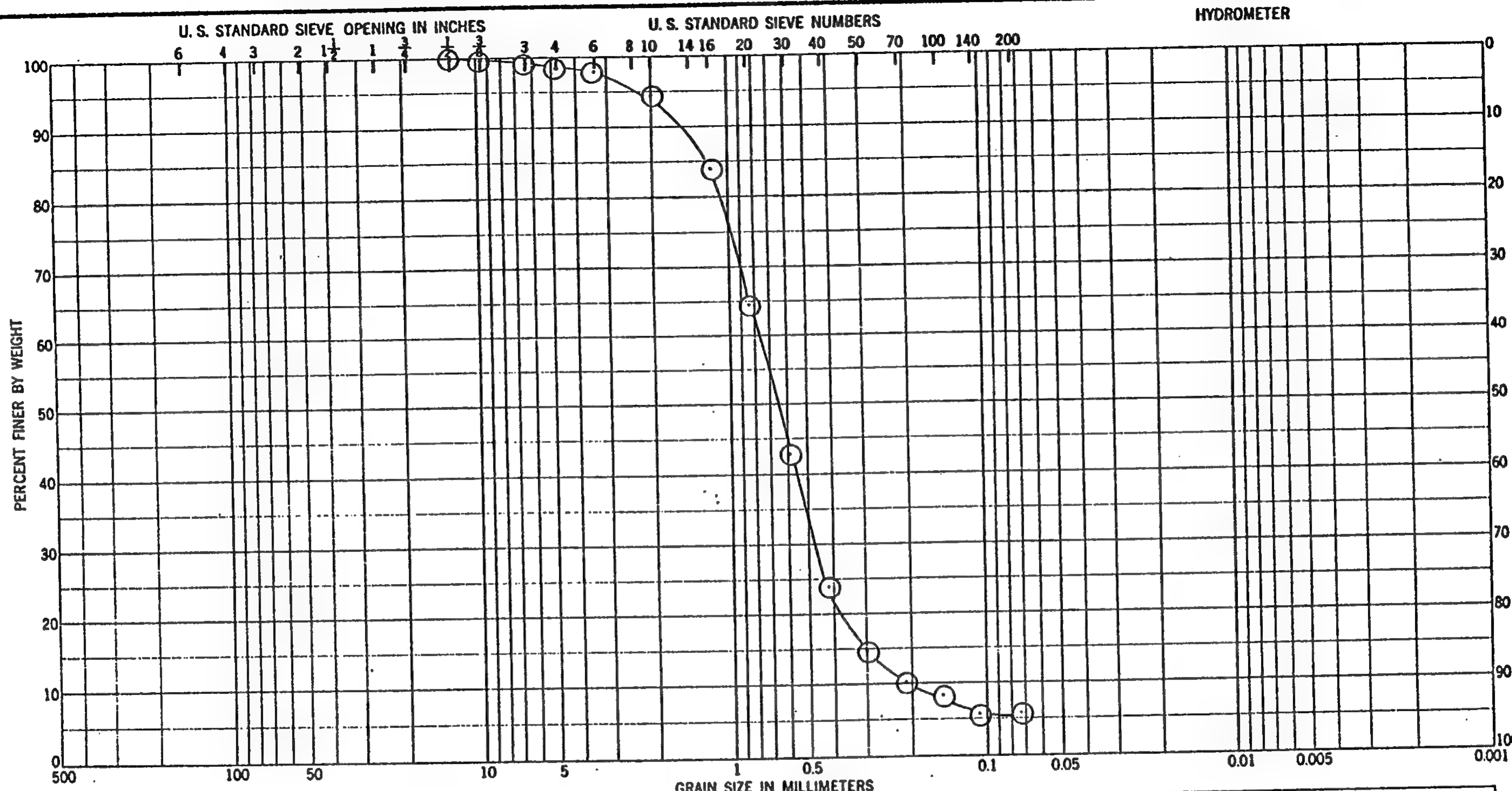
Area:

Boring No. 576

Date: 2 JULY 79

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

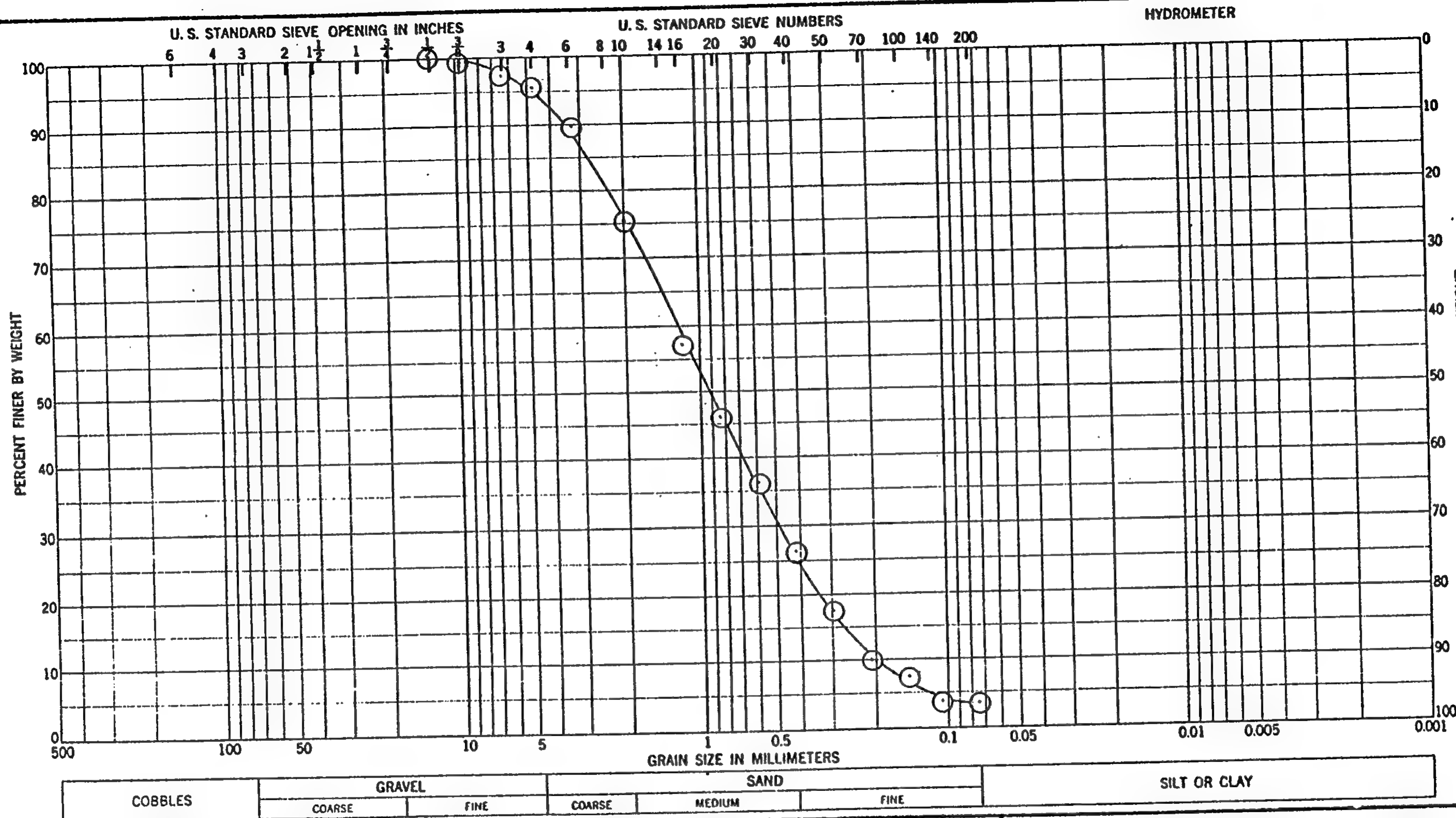
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	19.0-20.2	SILTY SAND (SP-SM) BROWN				

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	577
Date	2 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
14	44.5-46.0	SAND (SP) WITH TRACE GRAVEL BROWN				

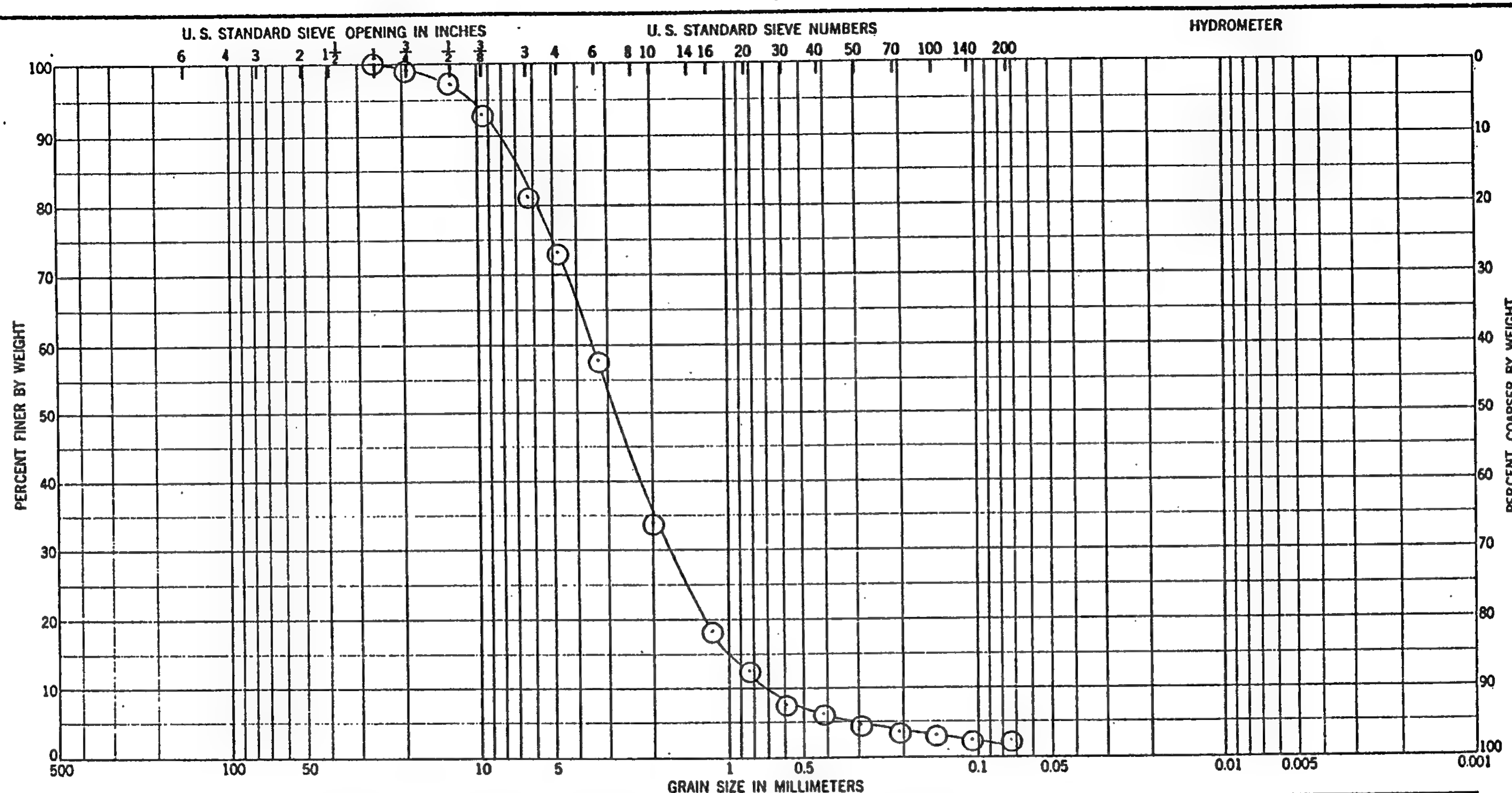
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	586
Date	3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A25

ENG FORM 1 MAY 63 2087



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
12	52.0-53.5	GRAVELLY SAND (SP) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

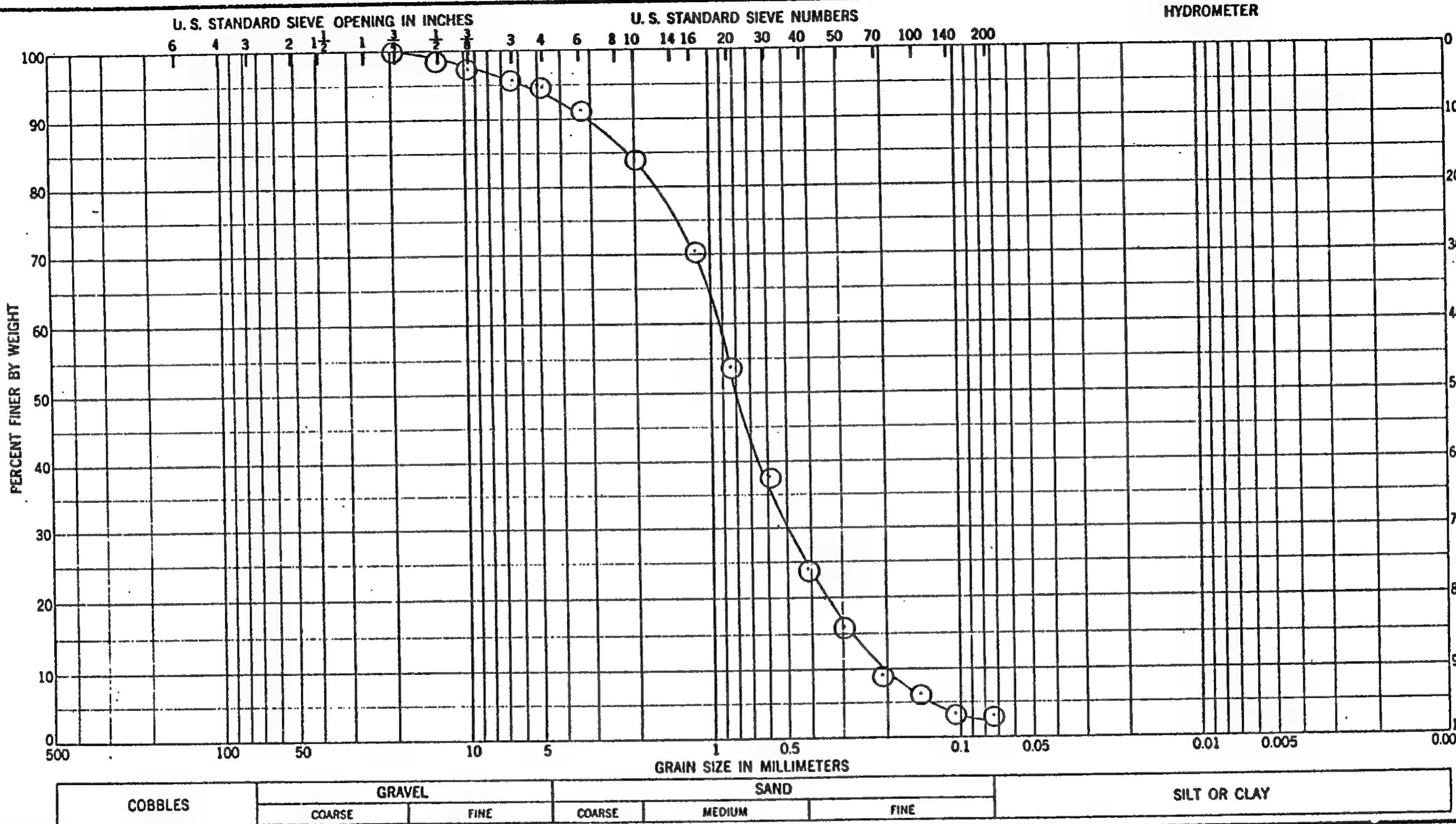
Boring No. 587

Date 3 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	29.0-30.2	SAND (SP) WITH GRAVEL TAN				

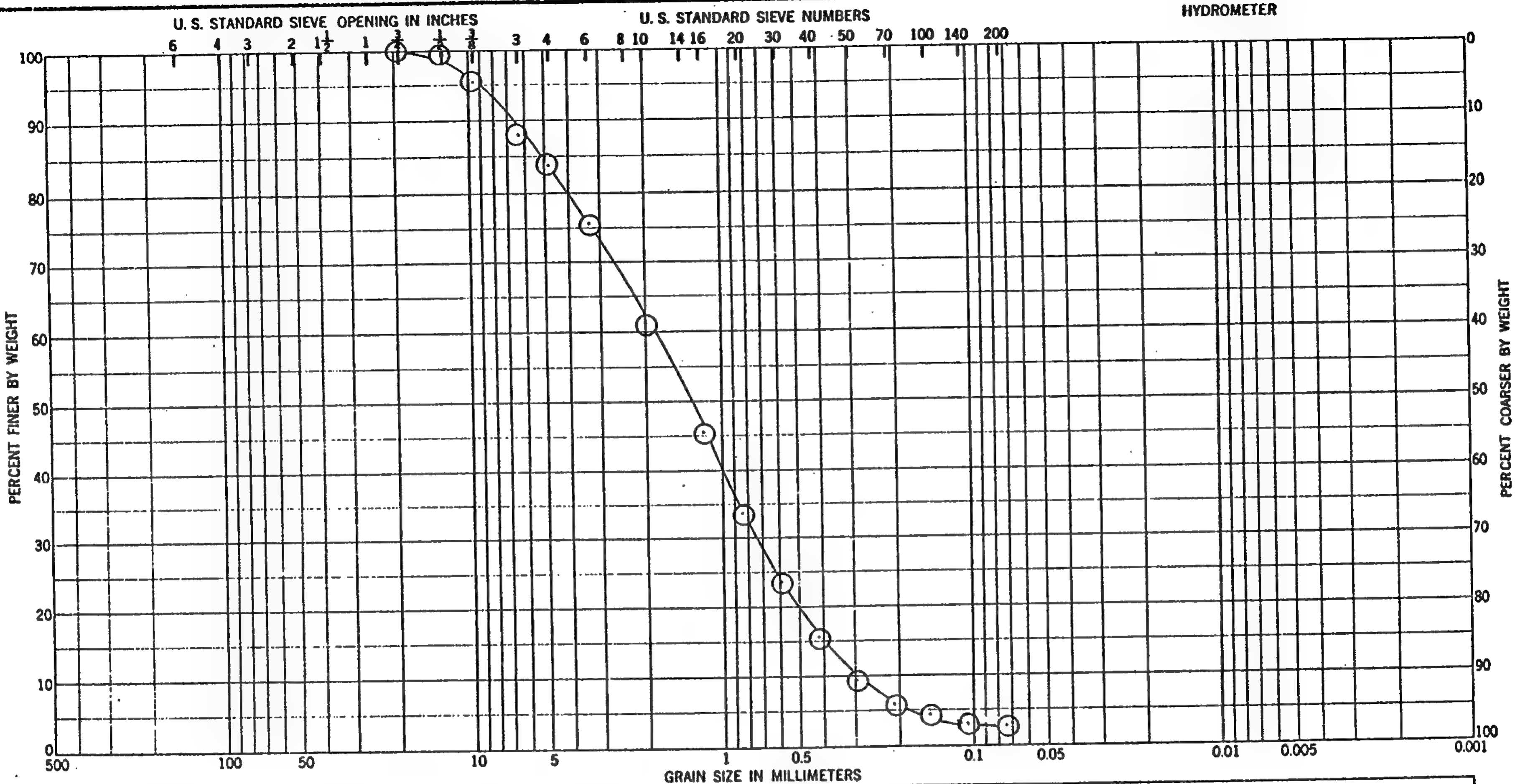
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	592
Date	3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A27



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	29.0-30.2	GRAVELLY SAND(SP) BROWN				

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

Area

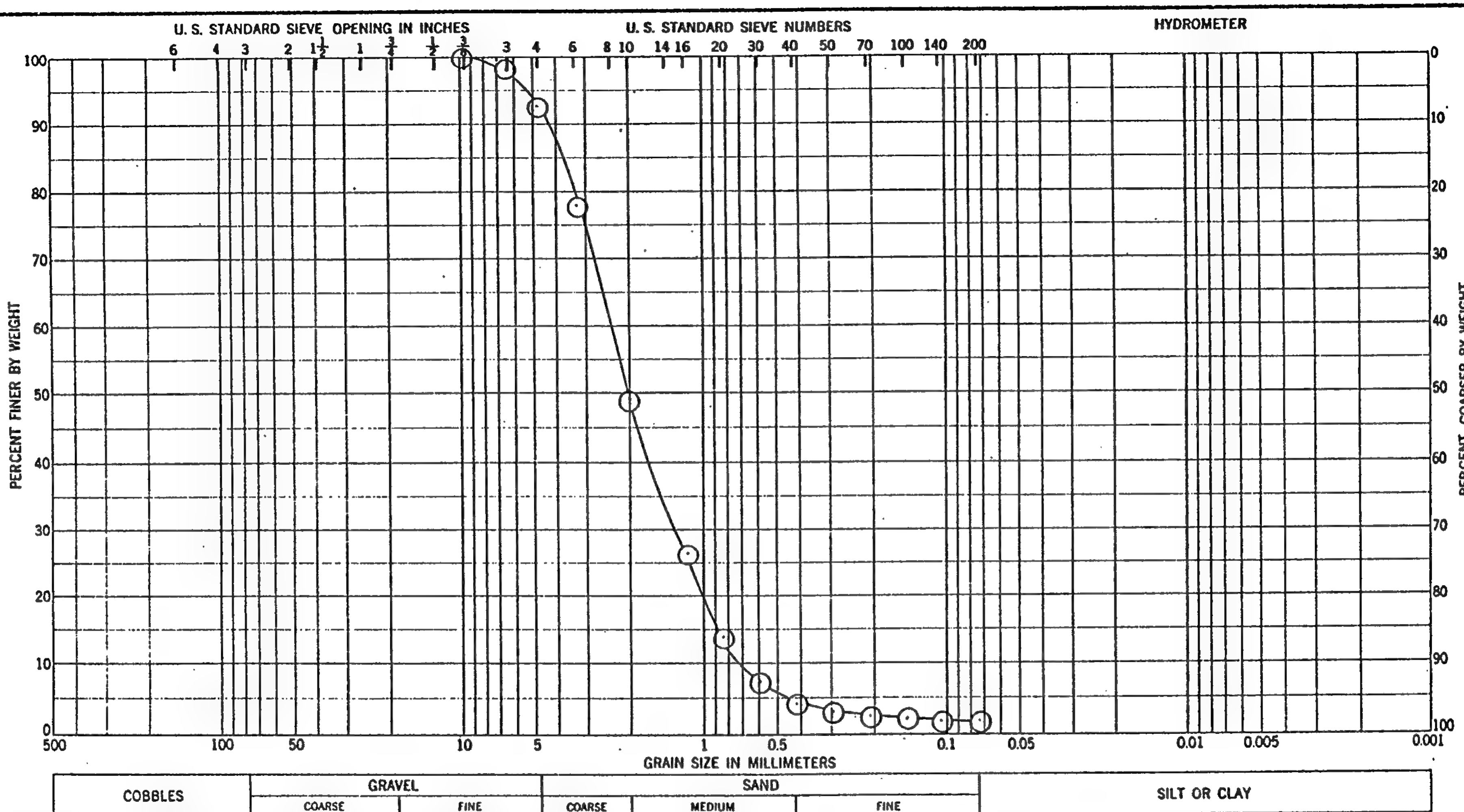
Boring No. 593

Date 3 JULY 79

Results of Sieve Analysis

Plate A28

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
9	31.5-33.0	SAND (SP) WITH GRAVEL TAN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No. 604

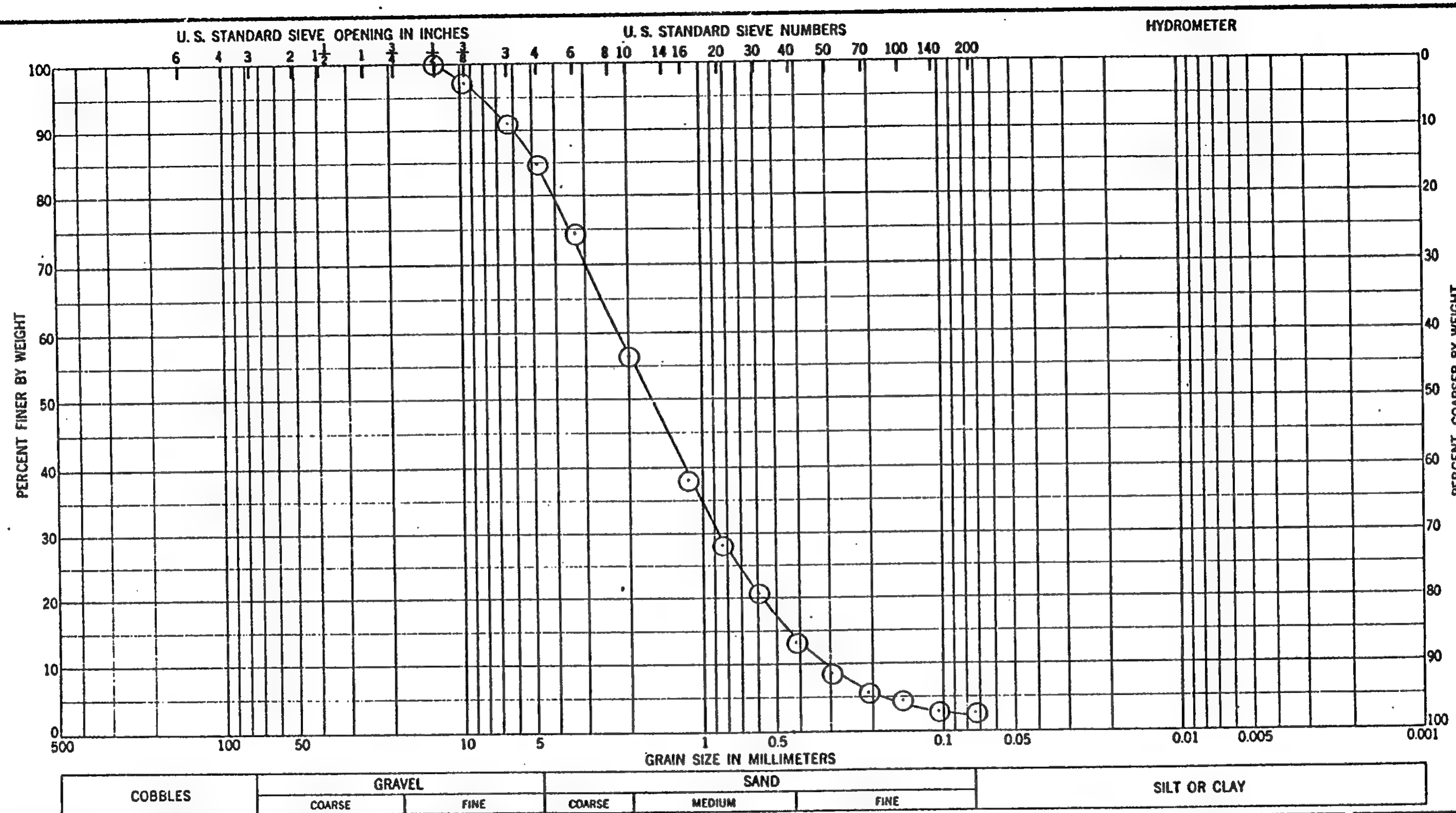
Date: 3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A29



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
9	34.0-35.0	GRAVELLY SAND (SW) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 605

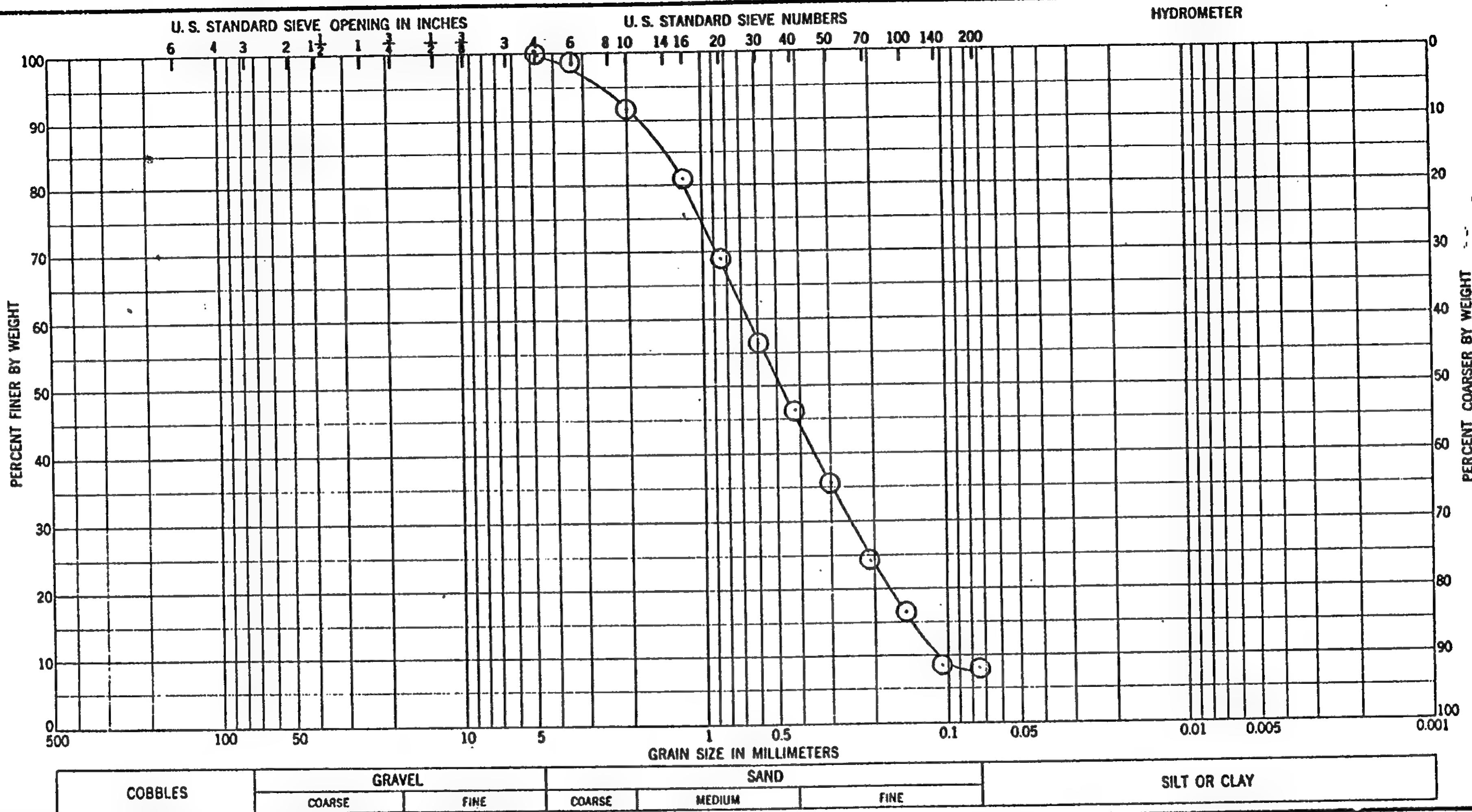
Date 3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A30



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
11	34.0-35.5	SILTY SAND (SP-SM) TAN				

GRADATION CURVES

Project: ROCKY MOUNTAIN ARSENAL

Area:

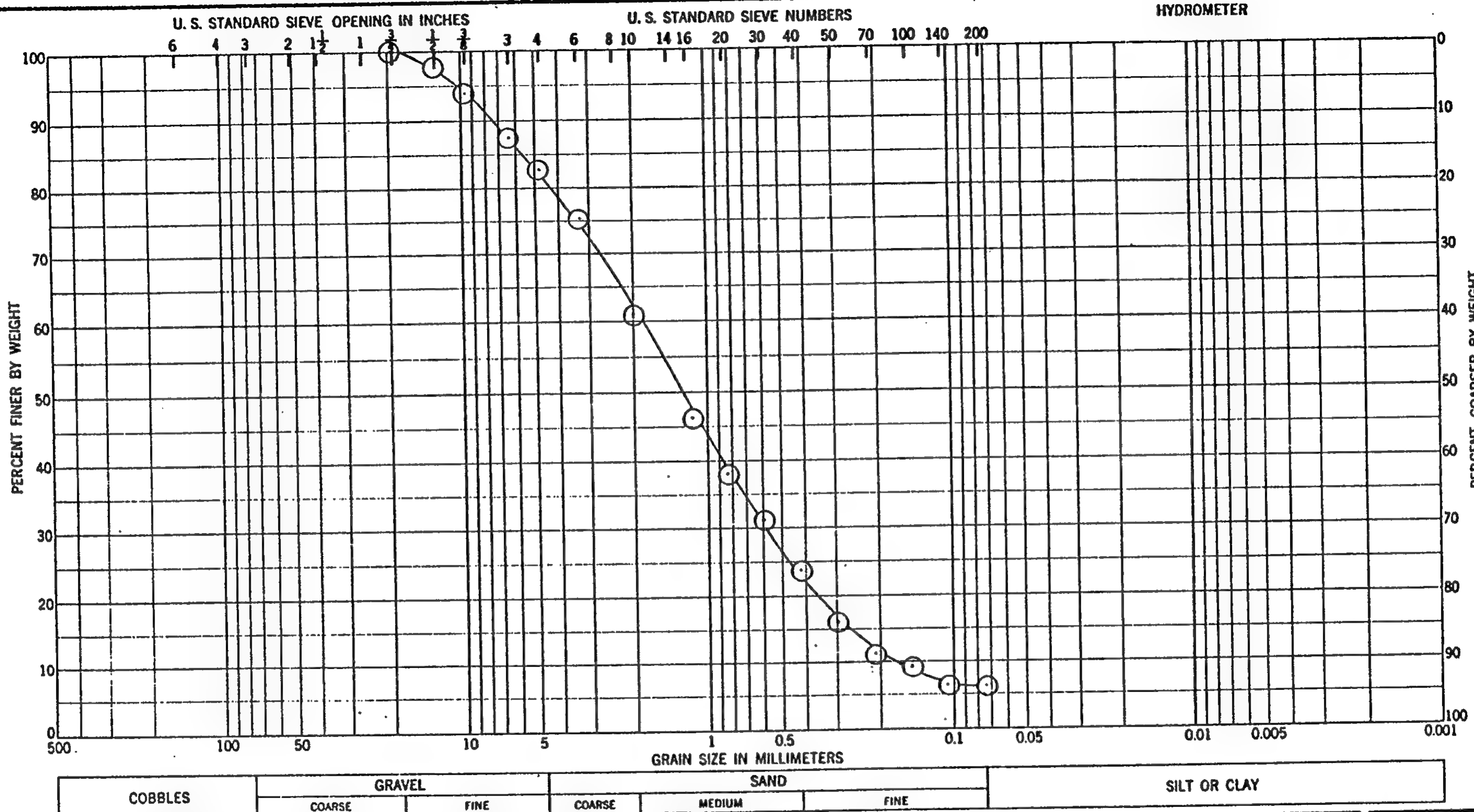
Boring No. 901

Date: 2 JULY 79

Results of Sieve Analysis

Plate A31

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
10	44.0-45.0	GRAVELLY SAND (SW-SM) BROWN				

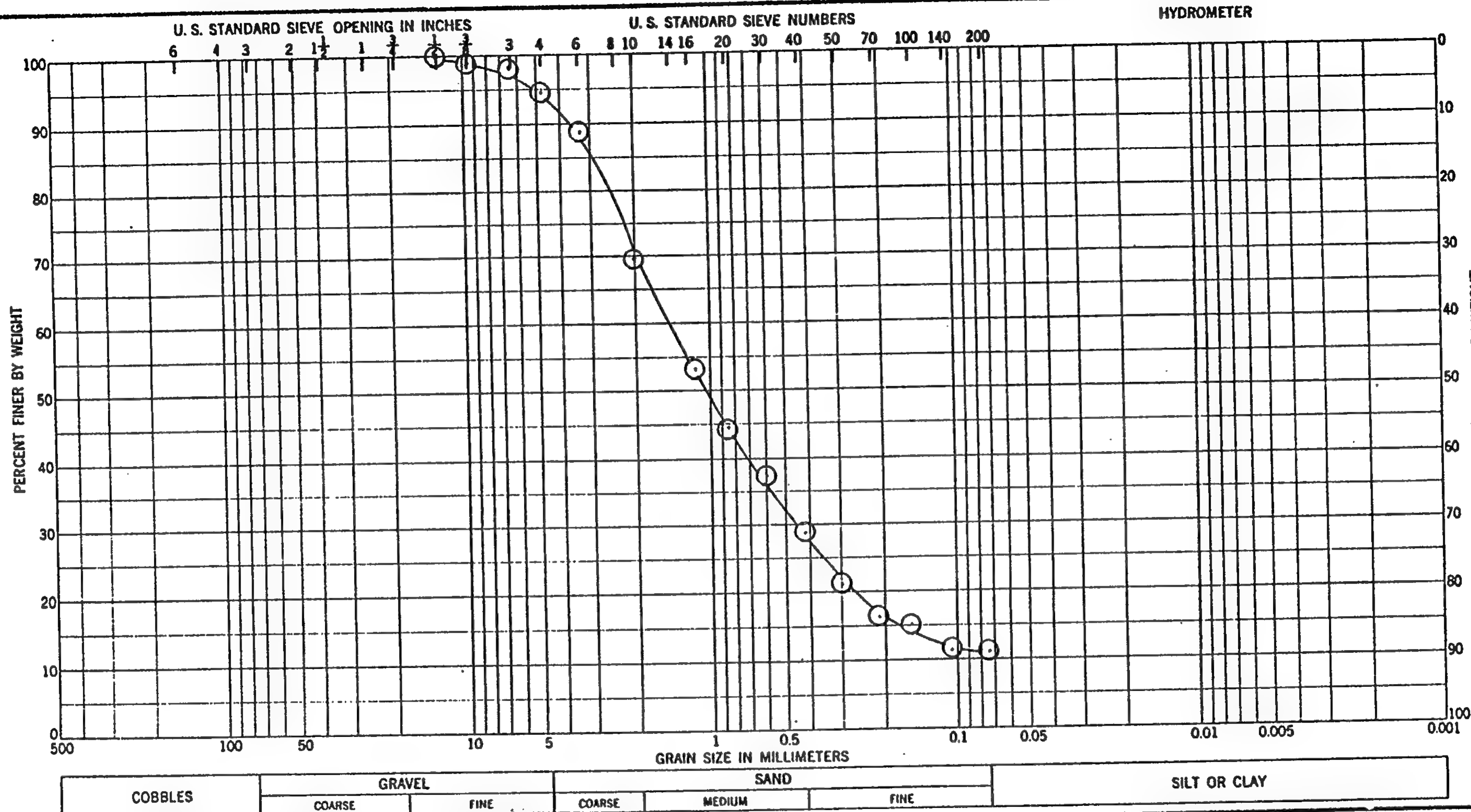
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	902
Date	2 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A32



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
12	54.0-55.5	SILTY SAND (SM) WITH GRAVEL TAN				

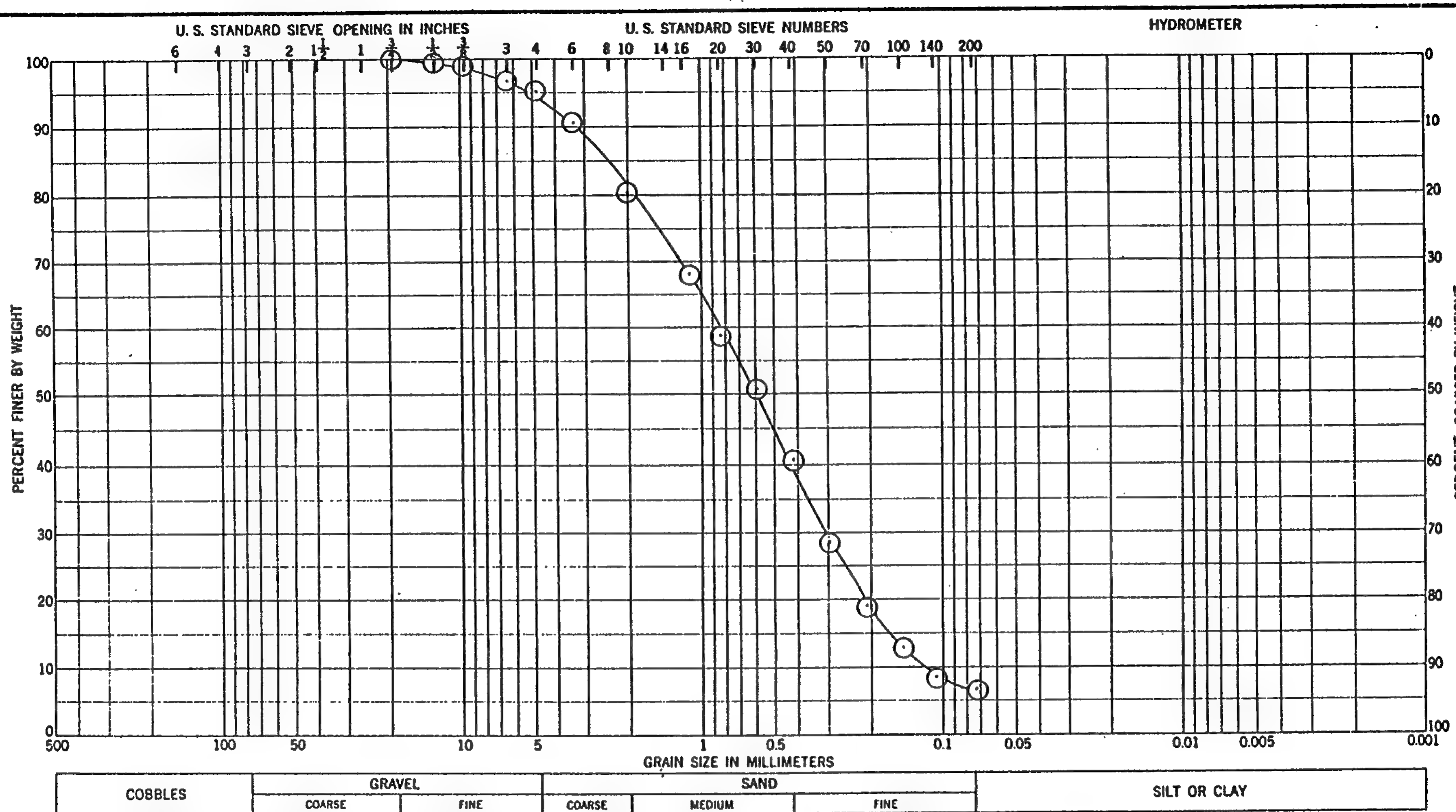
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	903
Date	2 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A33

ENG FORM 1 MAY 63 2087



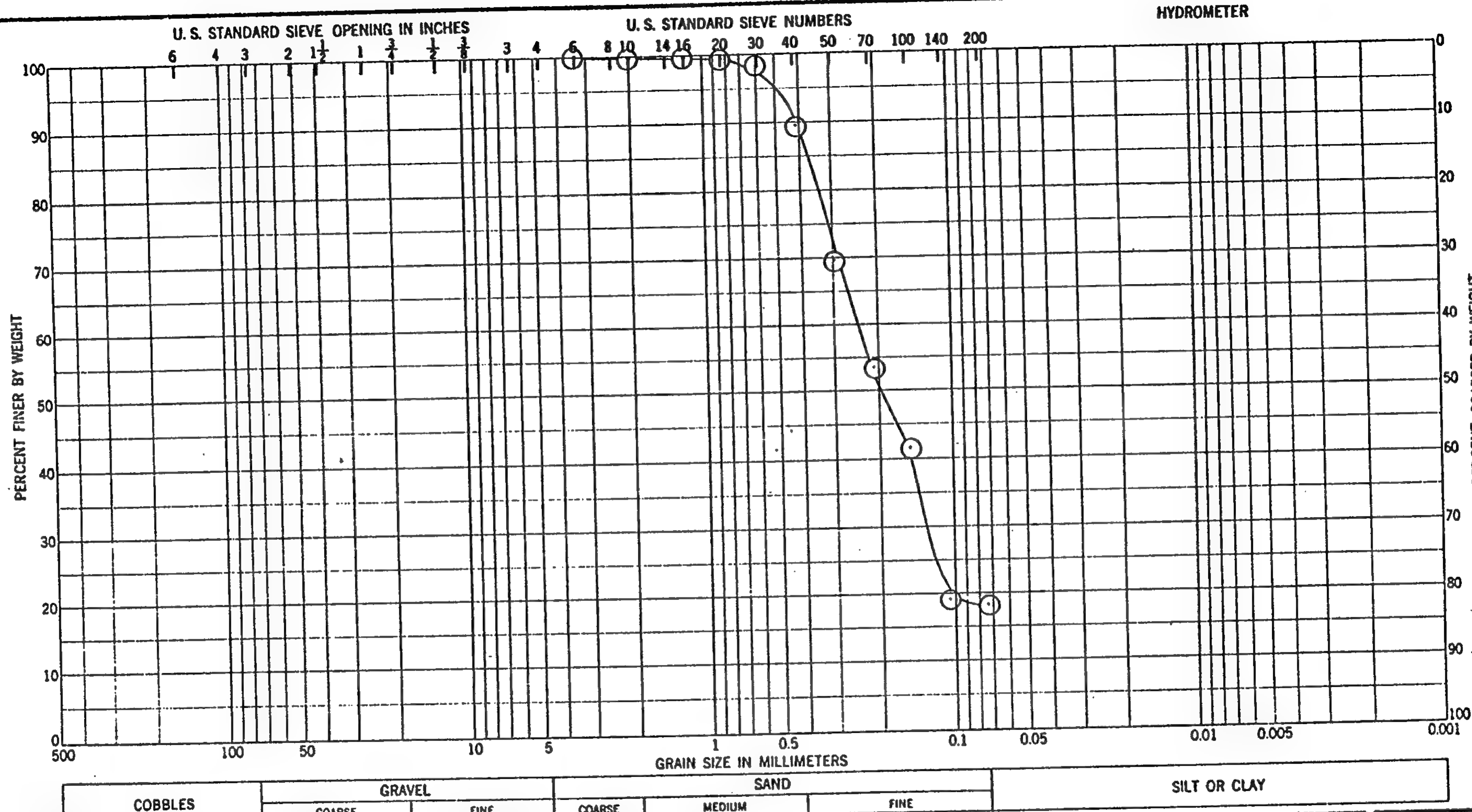
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
11	48.5-50.0	SILTY SAND (SP-SM) WITH TRACE GRAVEL BROWN				

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	904
Date	10 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-34.7	SILTY SAND (SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 905

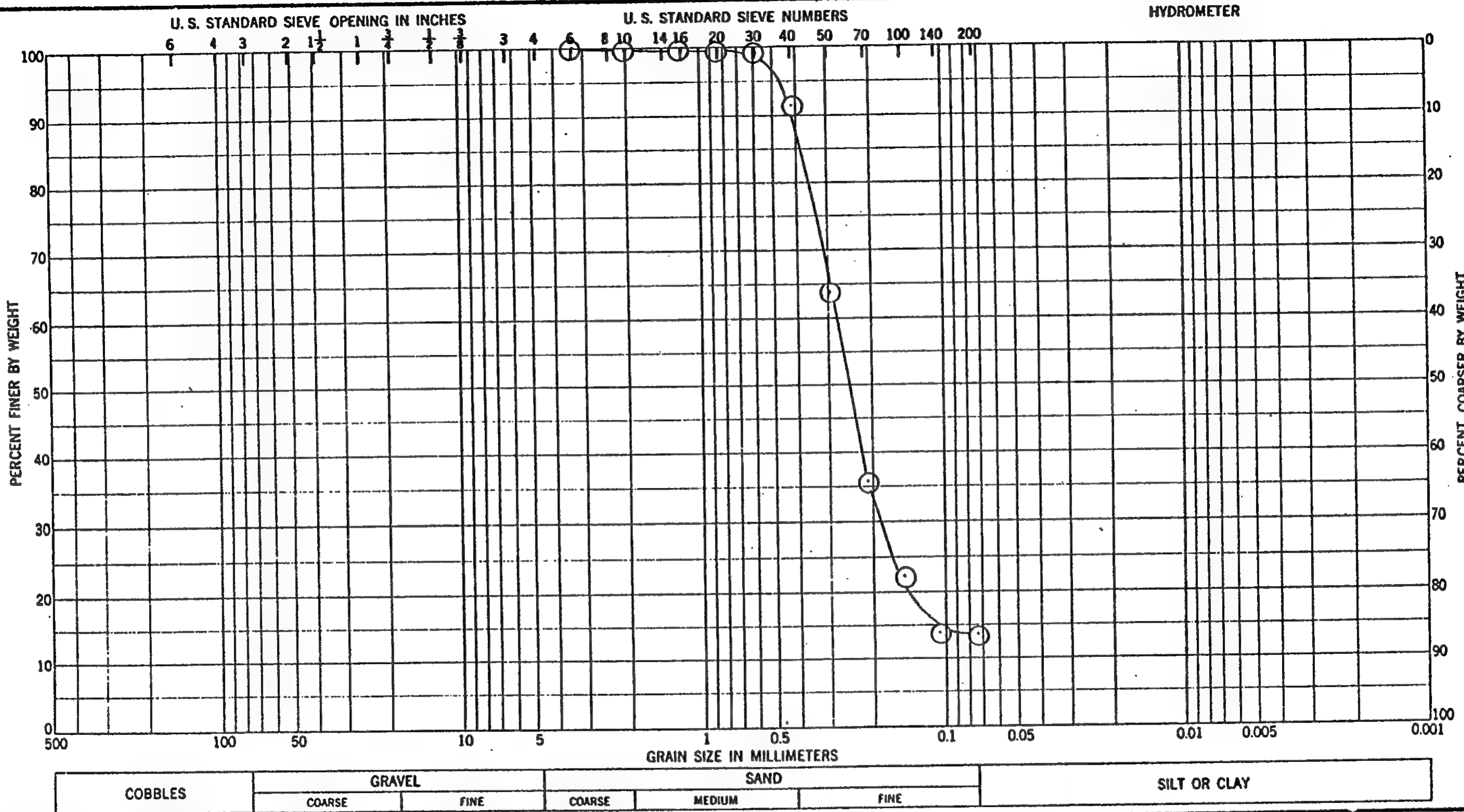
Date 3 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A35



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
9	39.0-39.8	SILTY SAND (SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 906

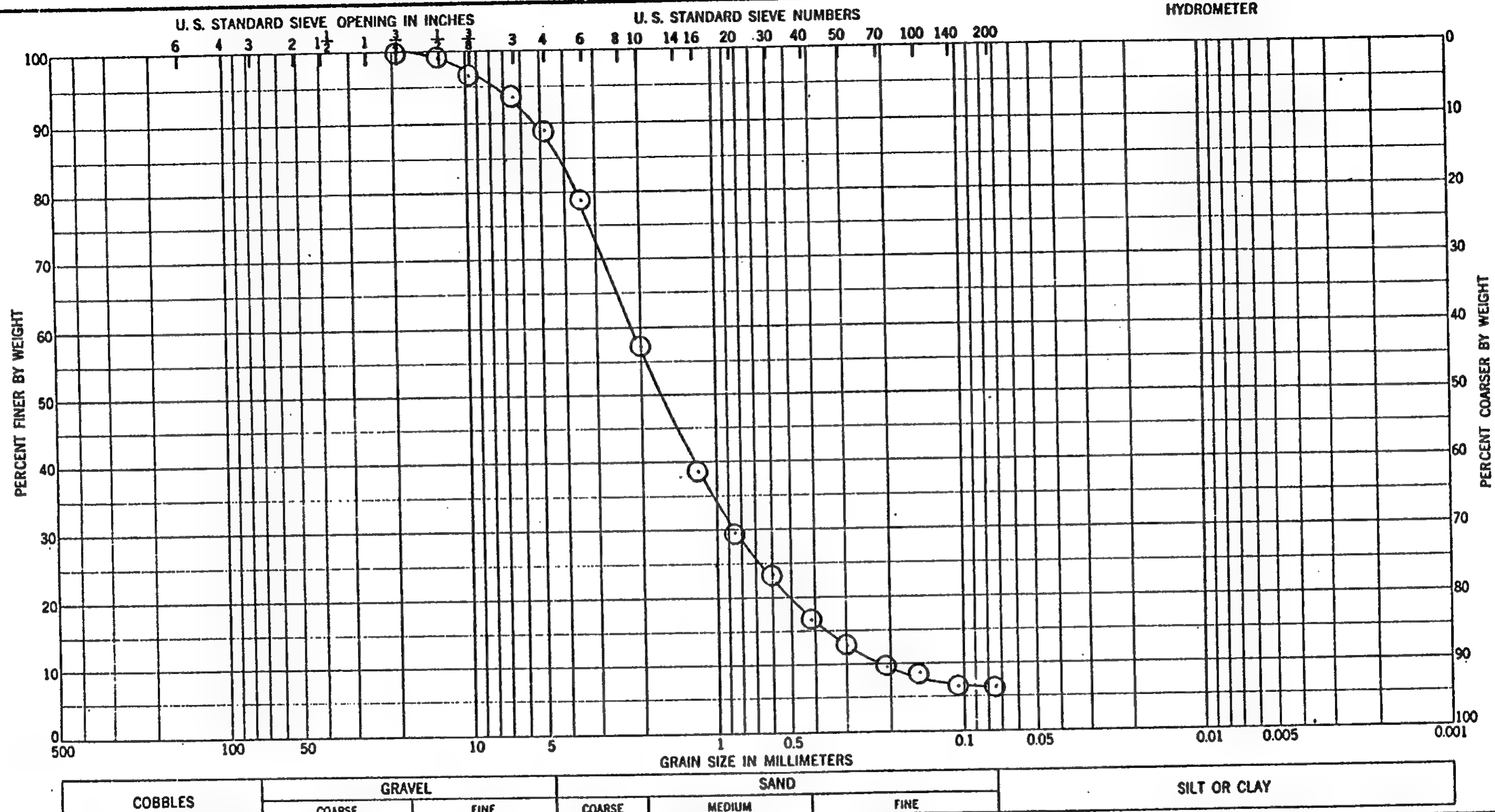
Date 2 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A36



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	SILTY SAND (SW-SM) WITH GRAVEL TAN				

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

Area

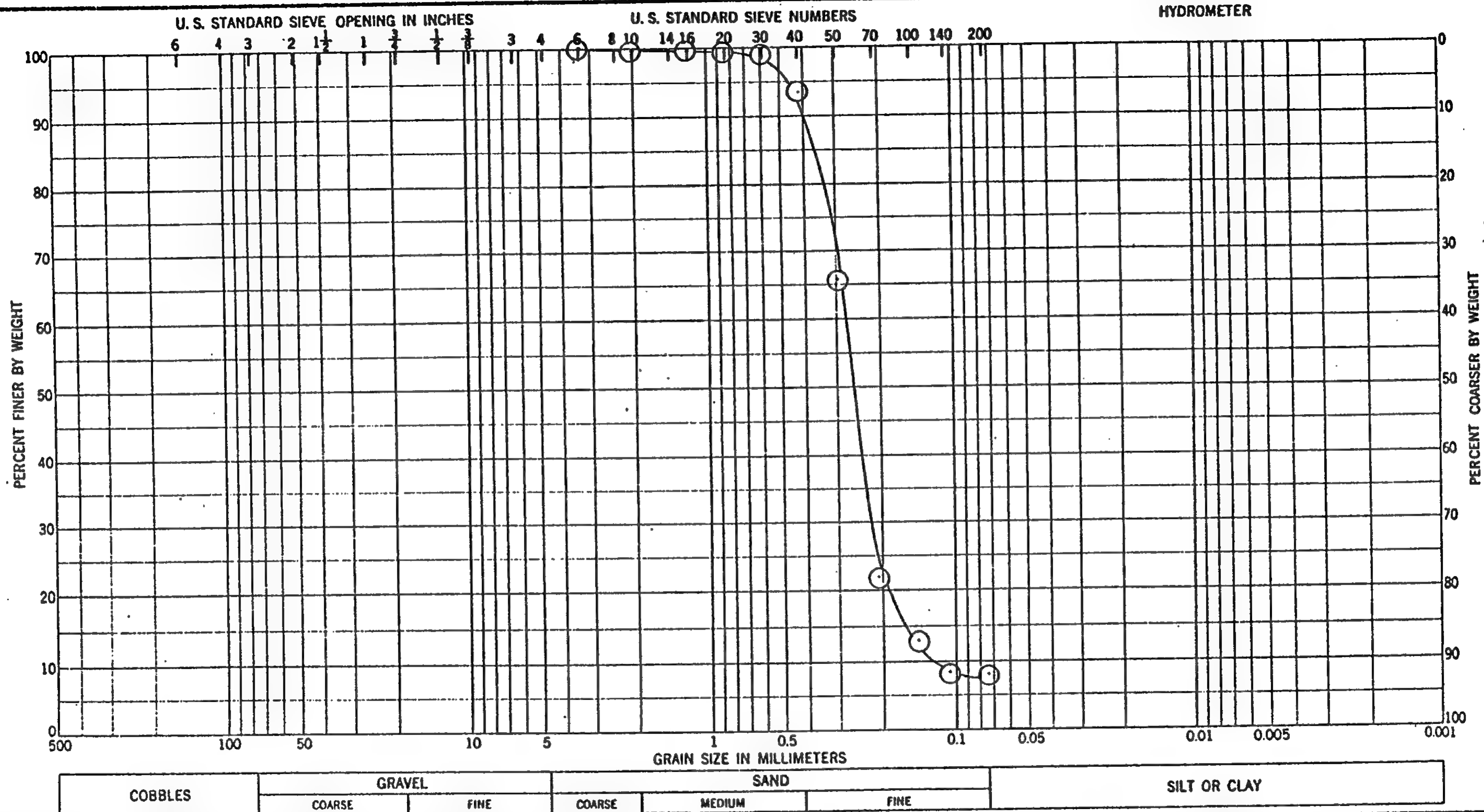
Boring No. 907

Date 3 JULY 79

Results of Sieve Analysis

Plate A37

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	SILTY SAND (SP-SM) TAN				

GRADATION CURVES

Project: ROCKY MOUNTAIN ARSENAL

Area:

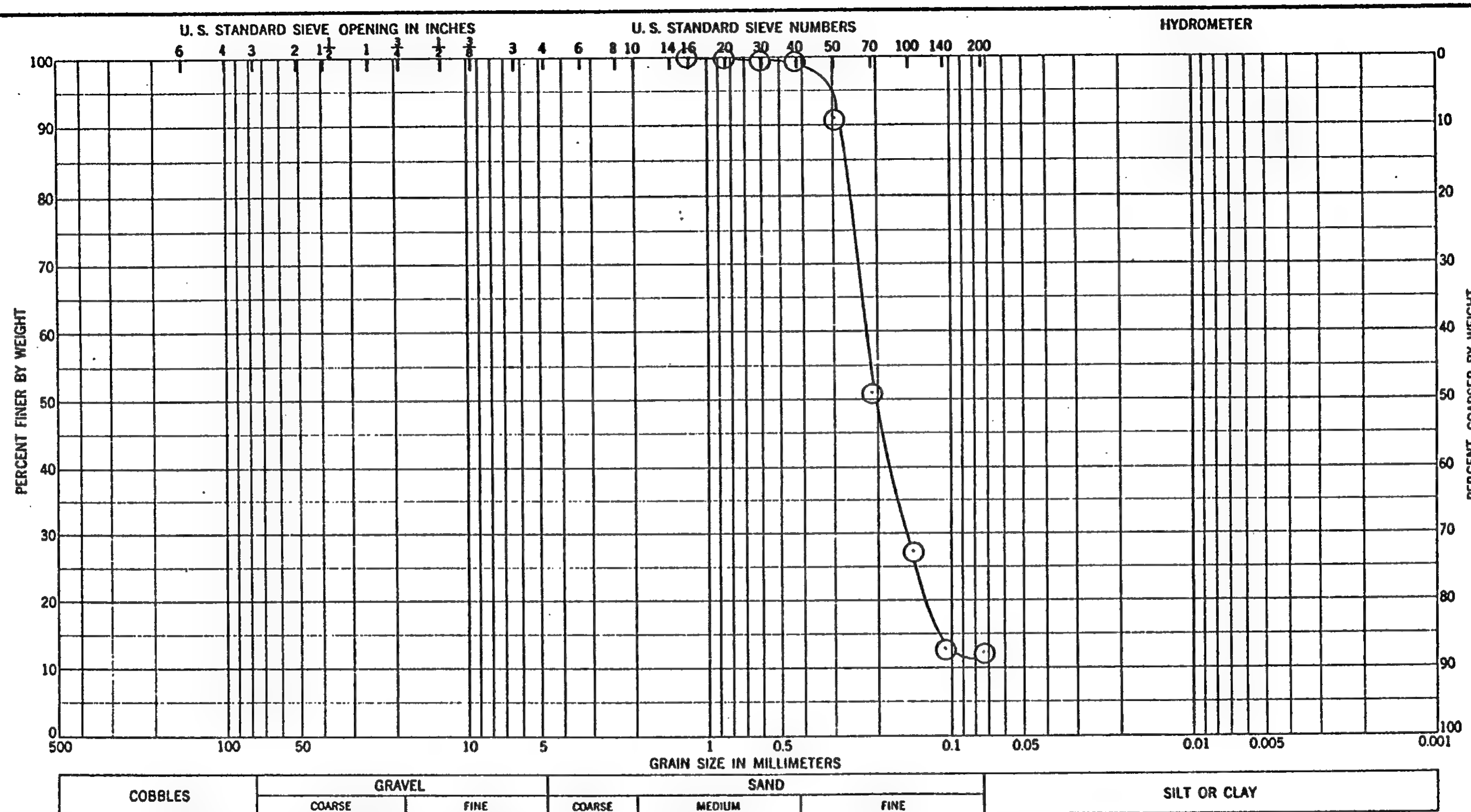
Boring No. 908

Date: 11 JULY 79

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A38



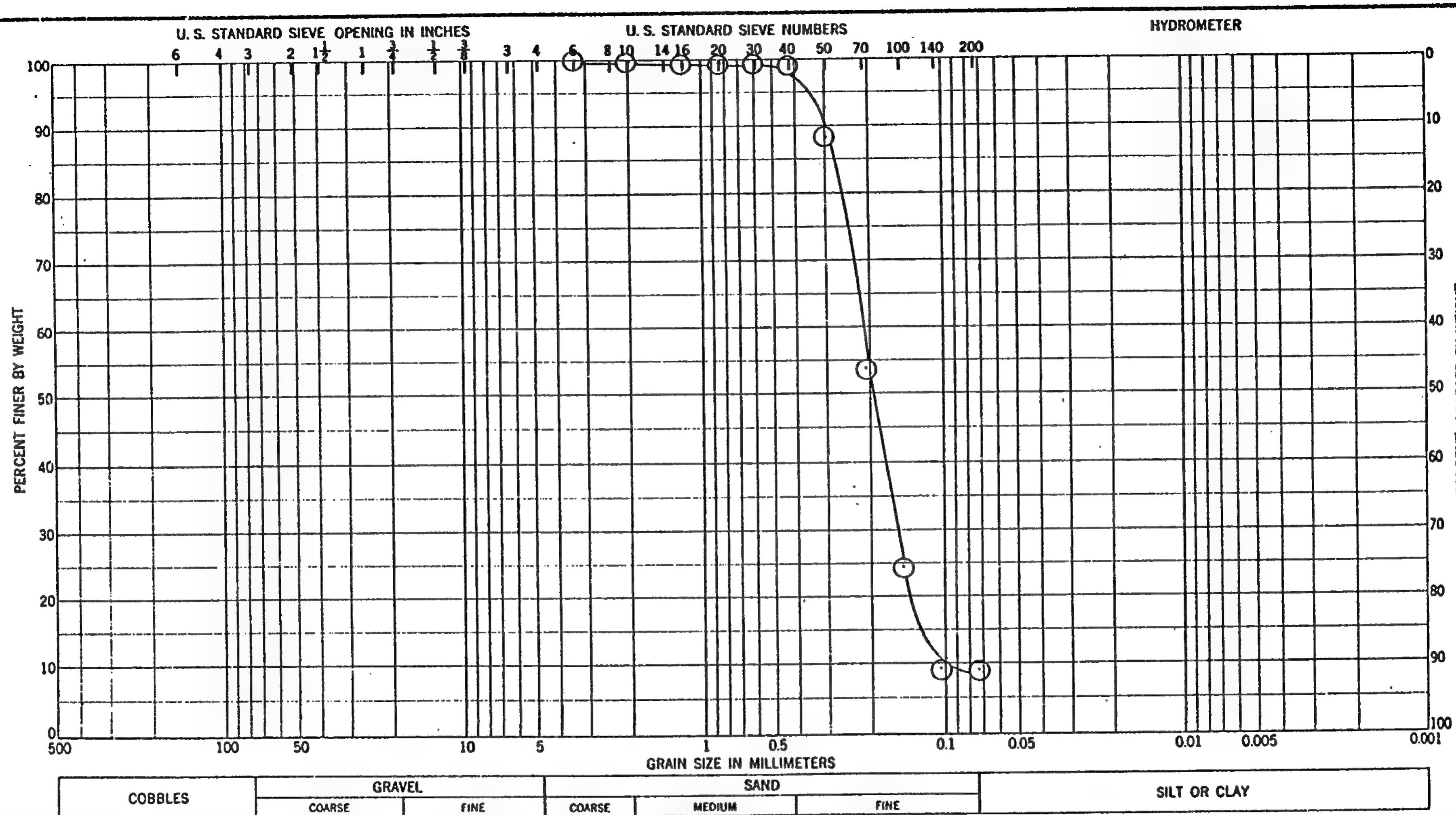
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
9	39.0-39.5	SILTY SAND (SM) TAN				

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	909
Date	3 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



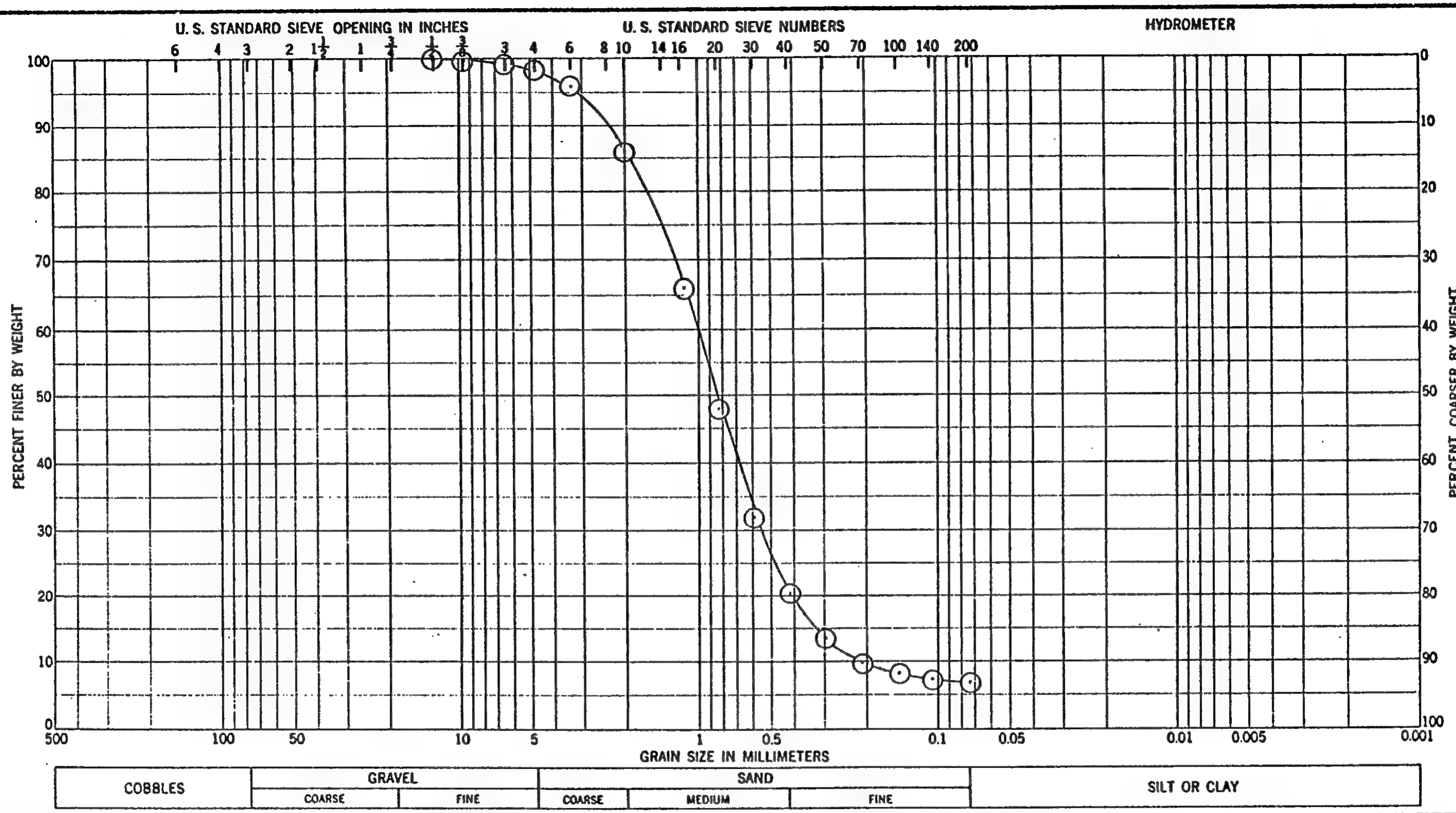
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	SILTY SAND (SP-SM) TAN				

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	910
Date	3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	19.0-20.5	SILTY SAND (SP-SM) TAN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No.: 911

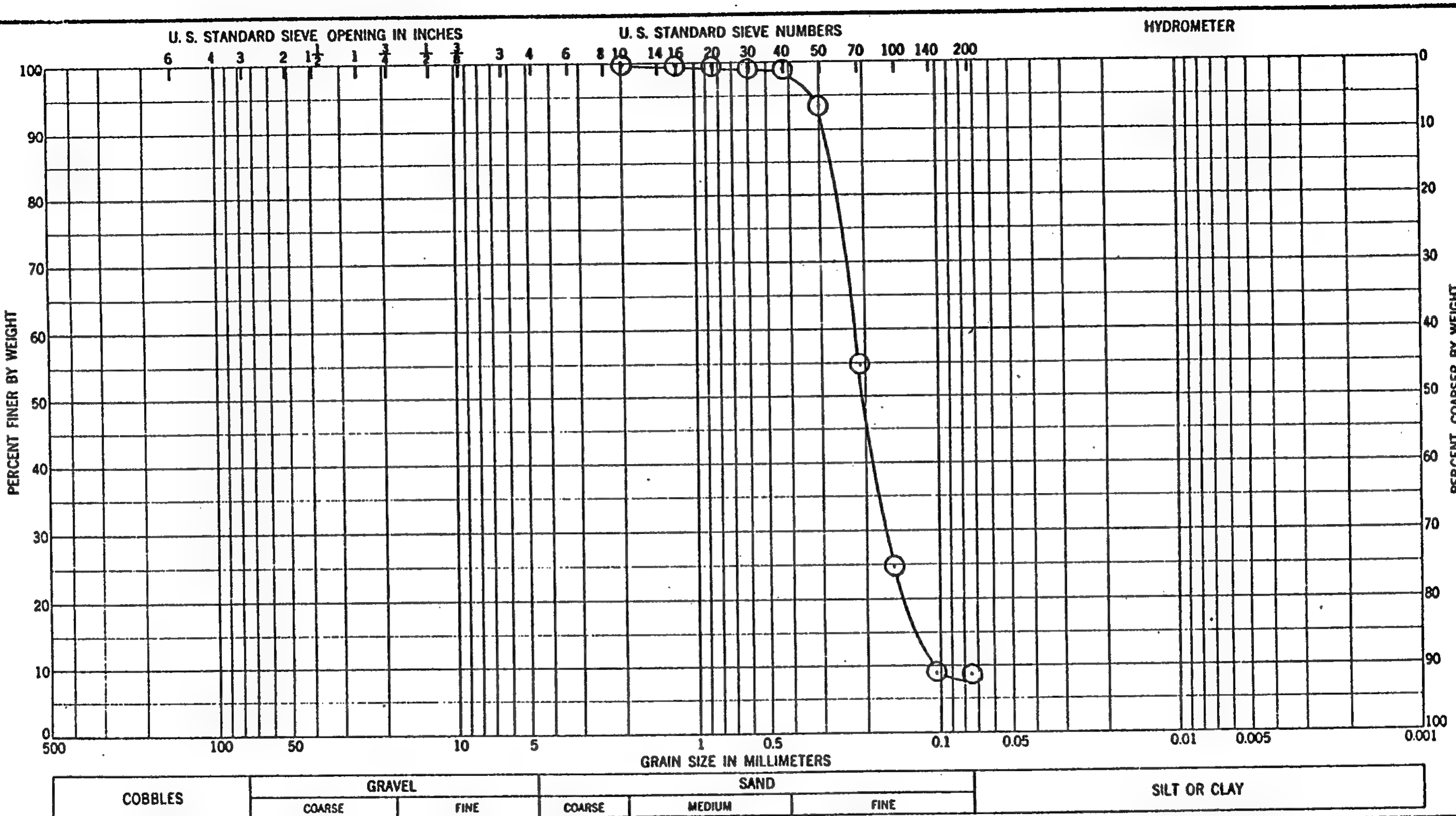
Date: 10 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A41



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	29.0-30.5	SILTY SAND (SP-SM) TAN				

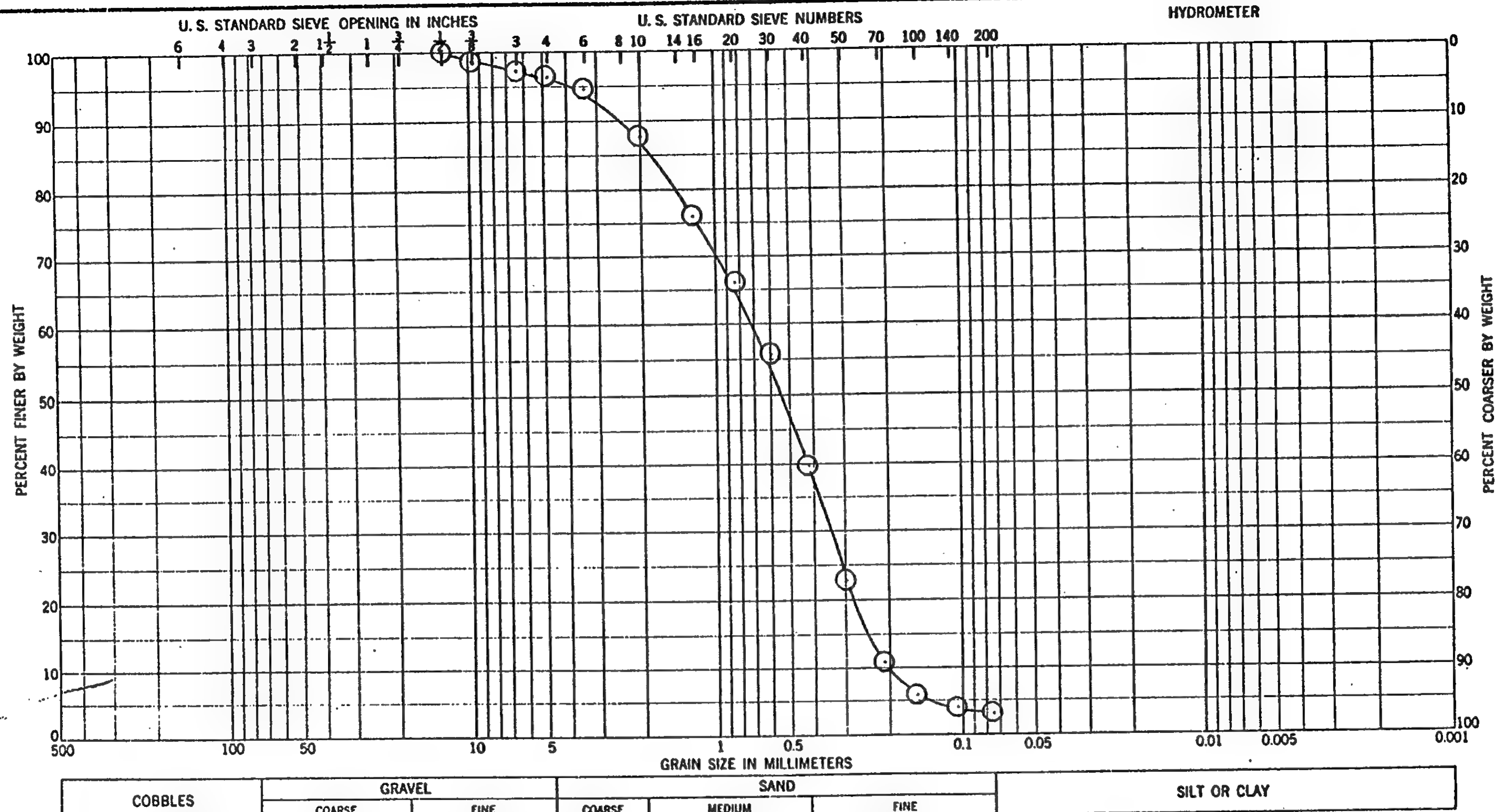
GRADATION CURVES

Project: RÓCKY MOUNTAIN ARSENAL
Area:
Boring No.: 911
Date: 2 JULY 79

Results of Sieve Analysis

Plate A42

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	29.0-30.5	SAND (SP) WITH TRACE GRAVEL TAN				

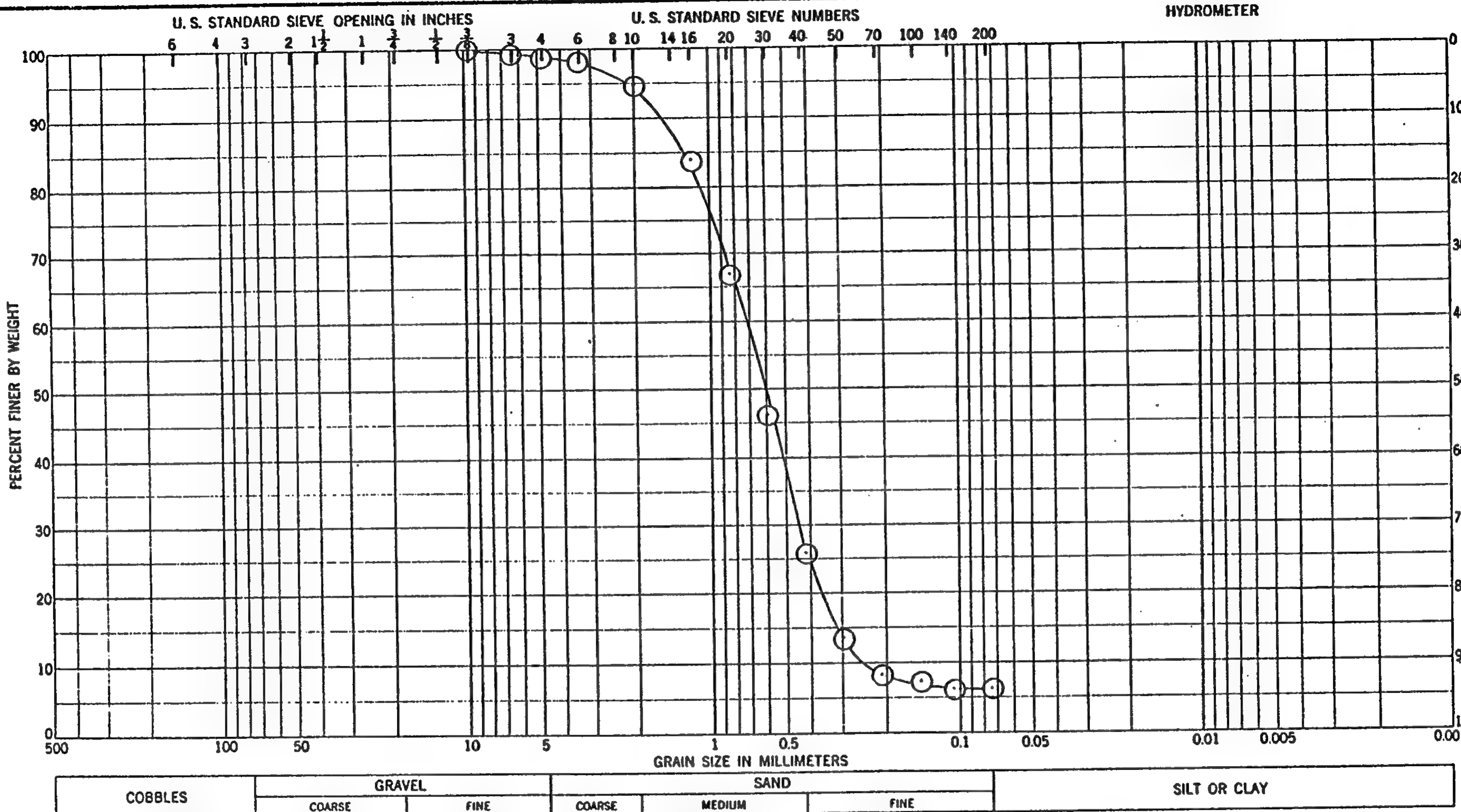
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	912
Date	11 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A43

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	24.0-25.5	SILTY SAND (SP-SM) TAN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No. 913

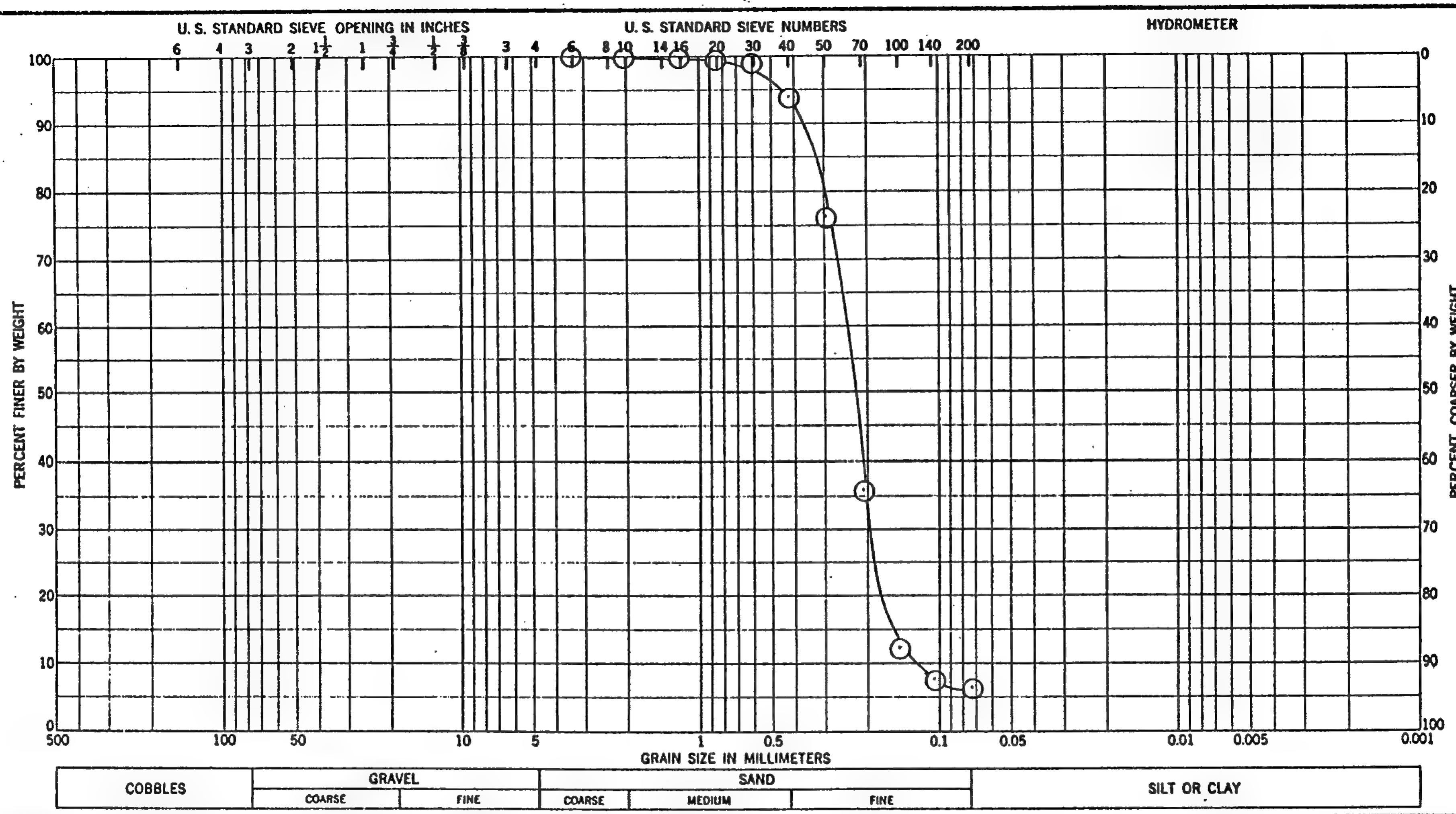
Date: 3 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A44



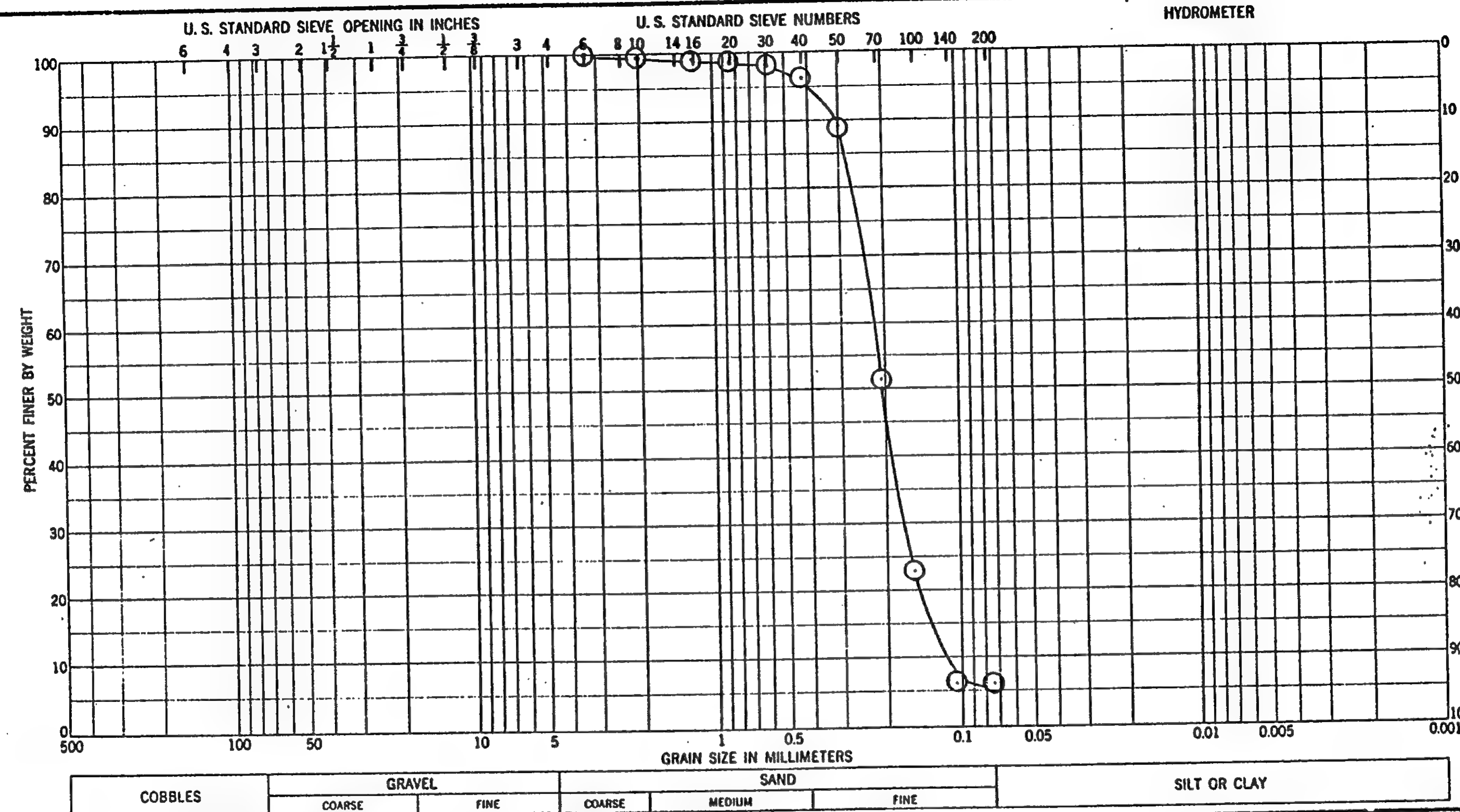
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	SILTY SAND (SP-SM) TAN				

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	914
Date	10 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	SILTY SAND (SP-SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

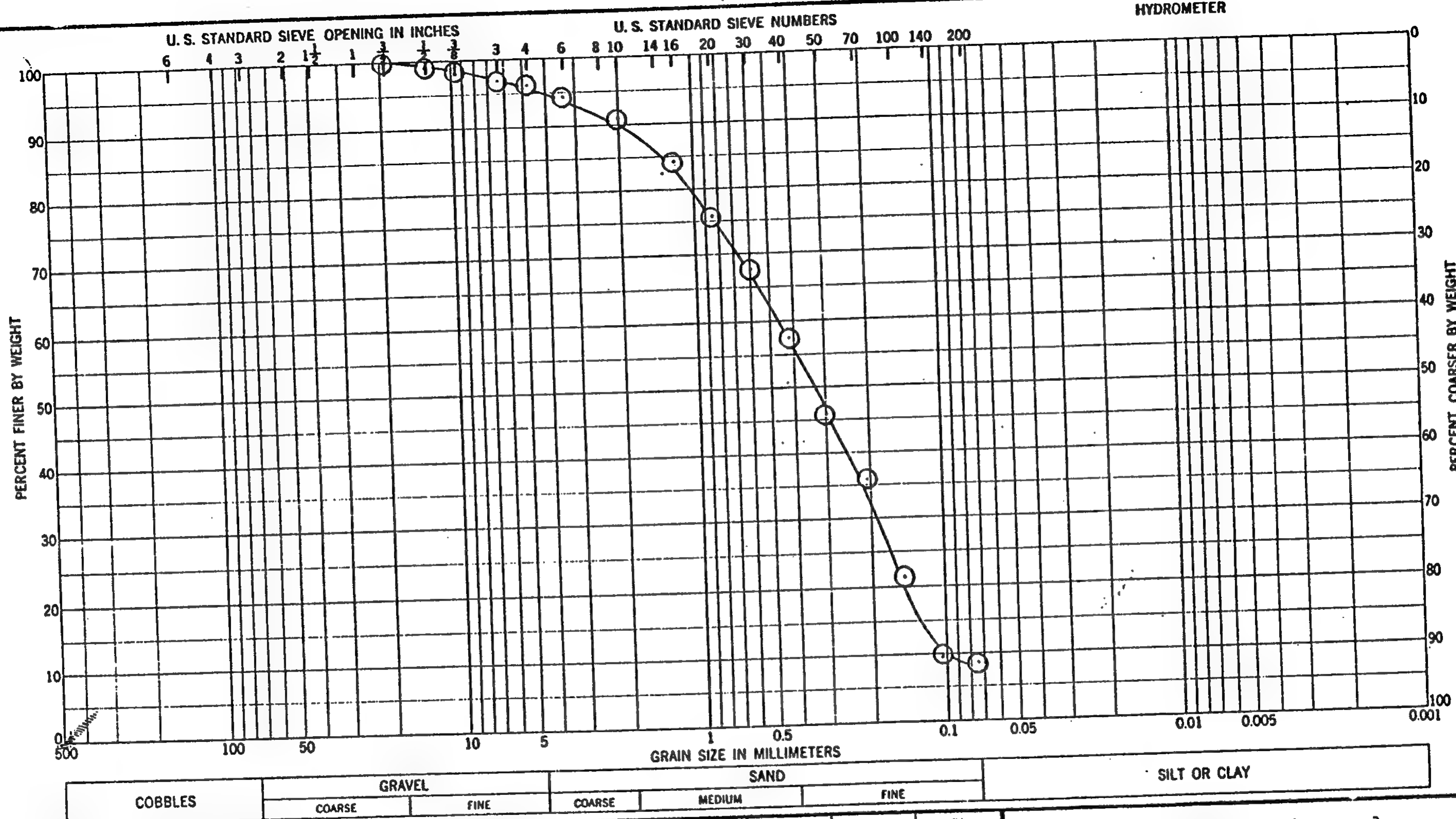
Boring No. 915

Date 2 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	24.0-25.5	Silty Sand (SP-SM) With Trace Gravel Tan				

Project Rocky Mountain Arsenal

Area

Boring No. 916

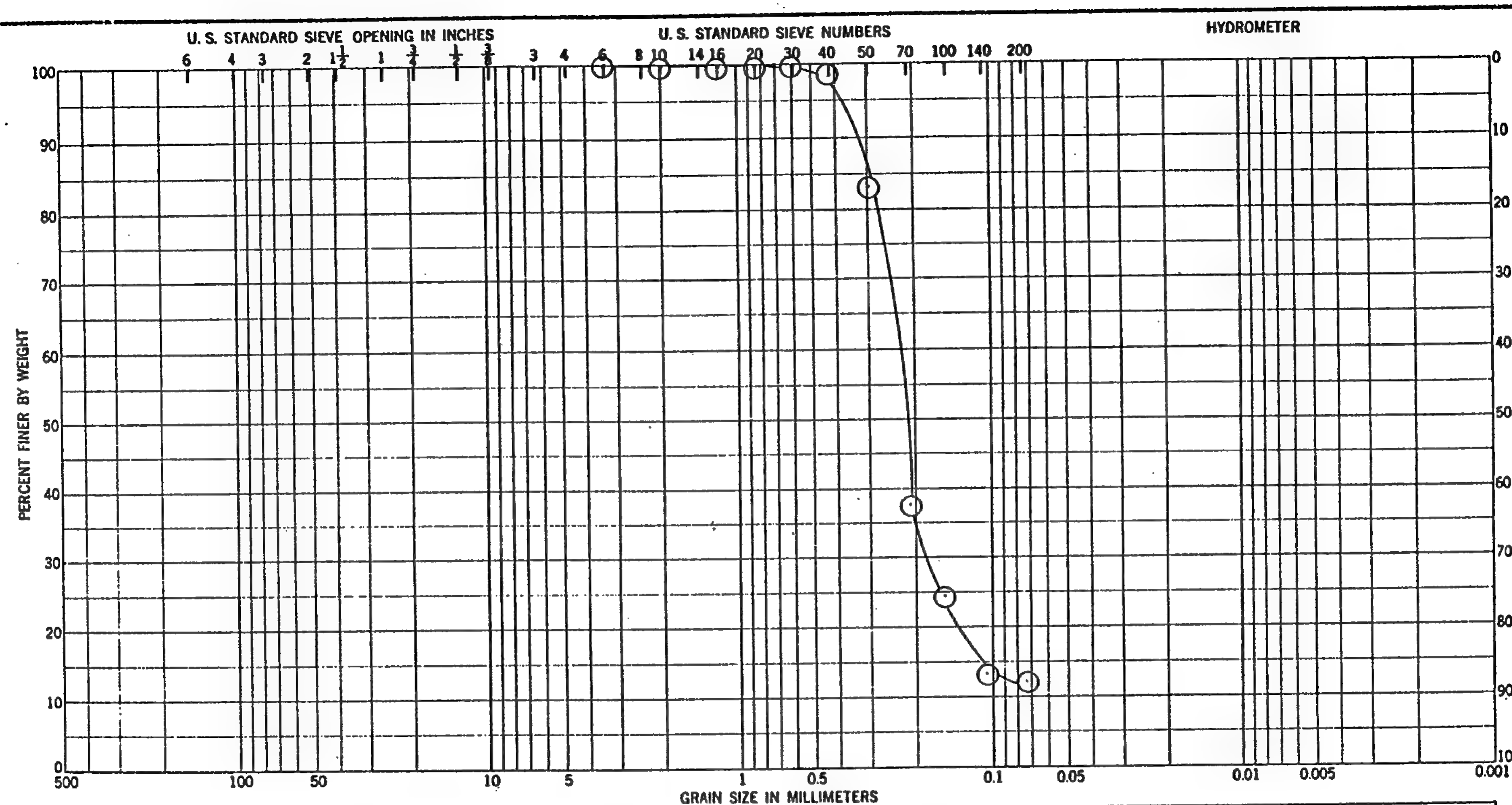
Date 2 July 79

GRADATION CURVES

Results of Sieve Analysis

Plate A47

ENG FORM 1 MAY 63 2087



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	35.0-36.5	SILTY SAND (SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 917

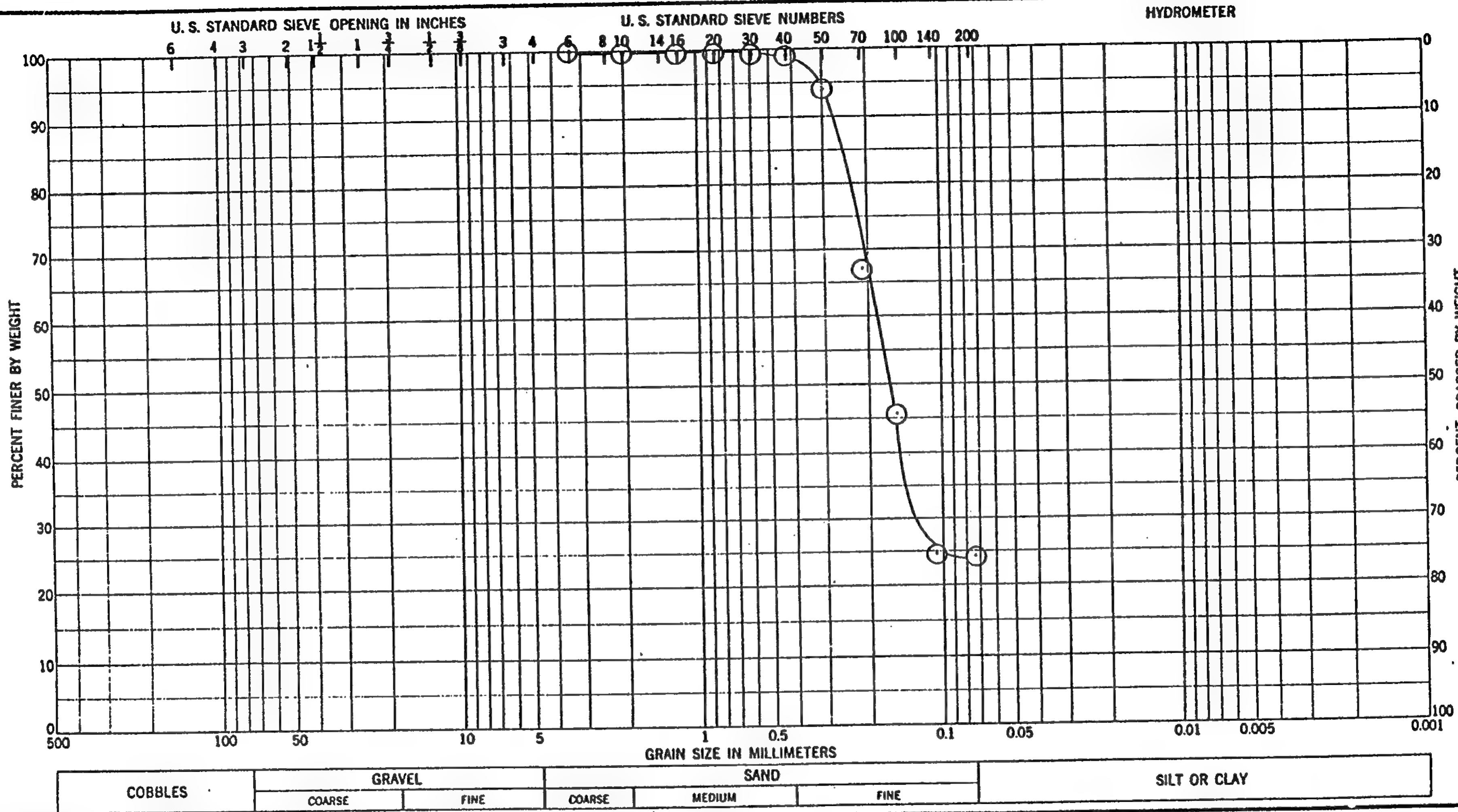
Date 3 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A48



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	SILTY SAND (SM) TAN				

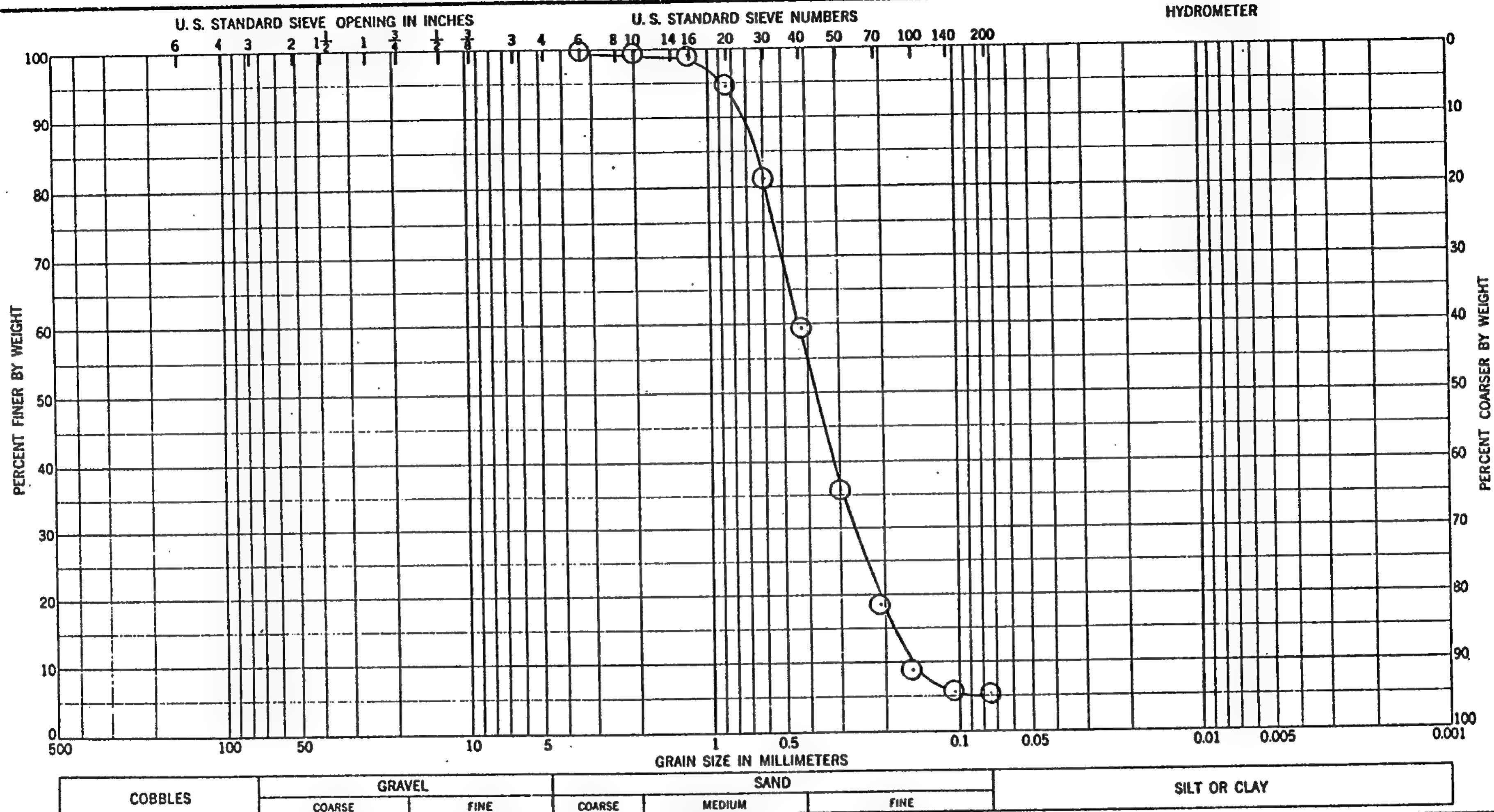
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	918
Date	3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A49



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	SILTY SAND (SP-SM) TAN				

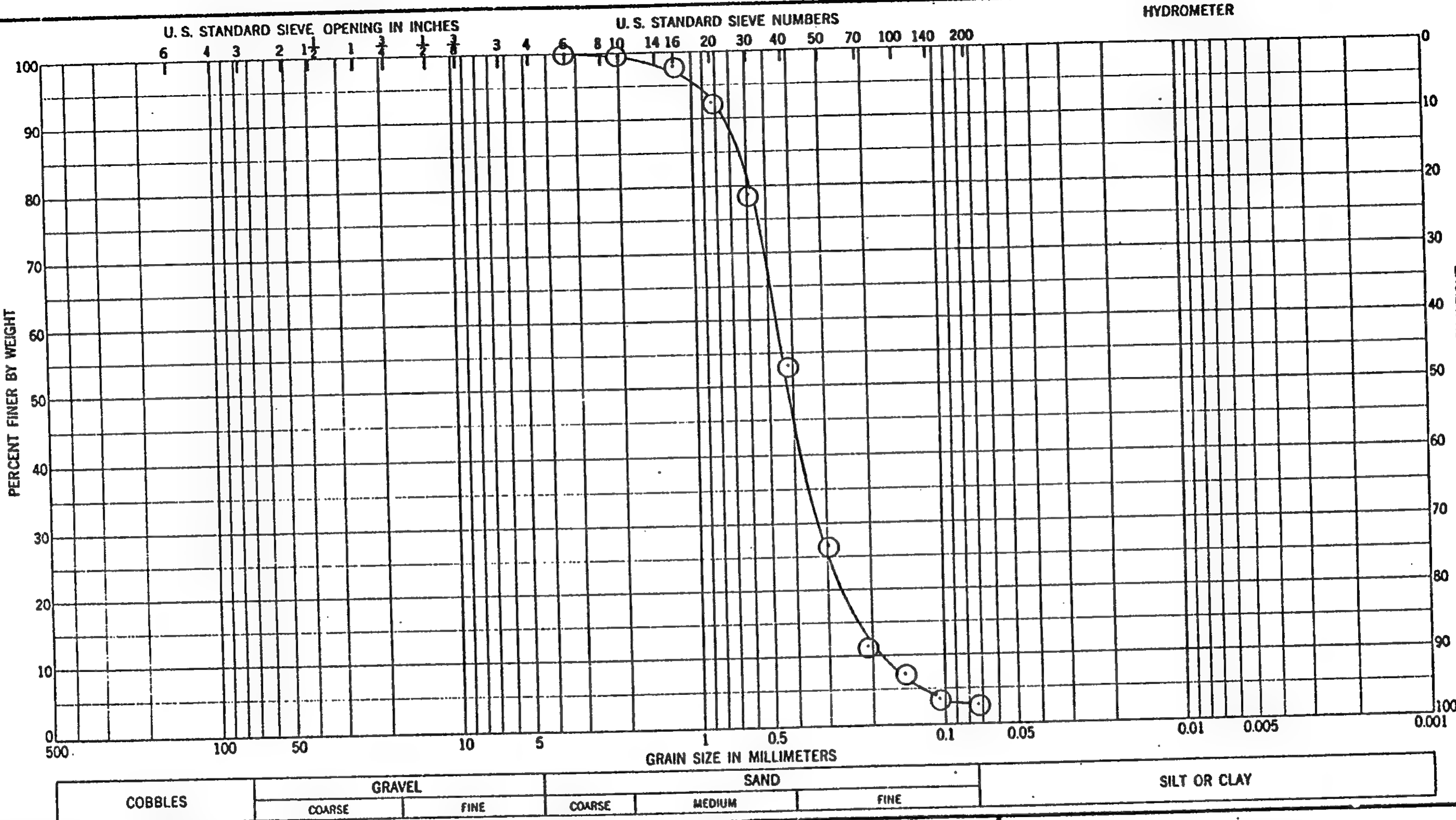
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	919
Date	10 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A50



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	24.0-25.5	SAND (SP) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

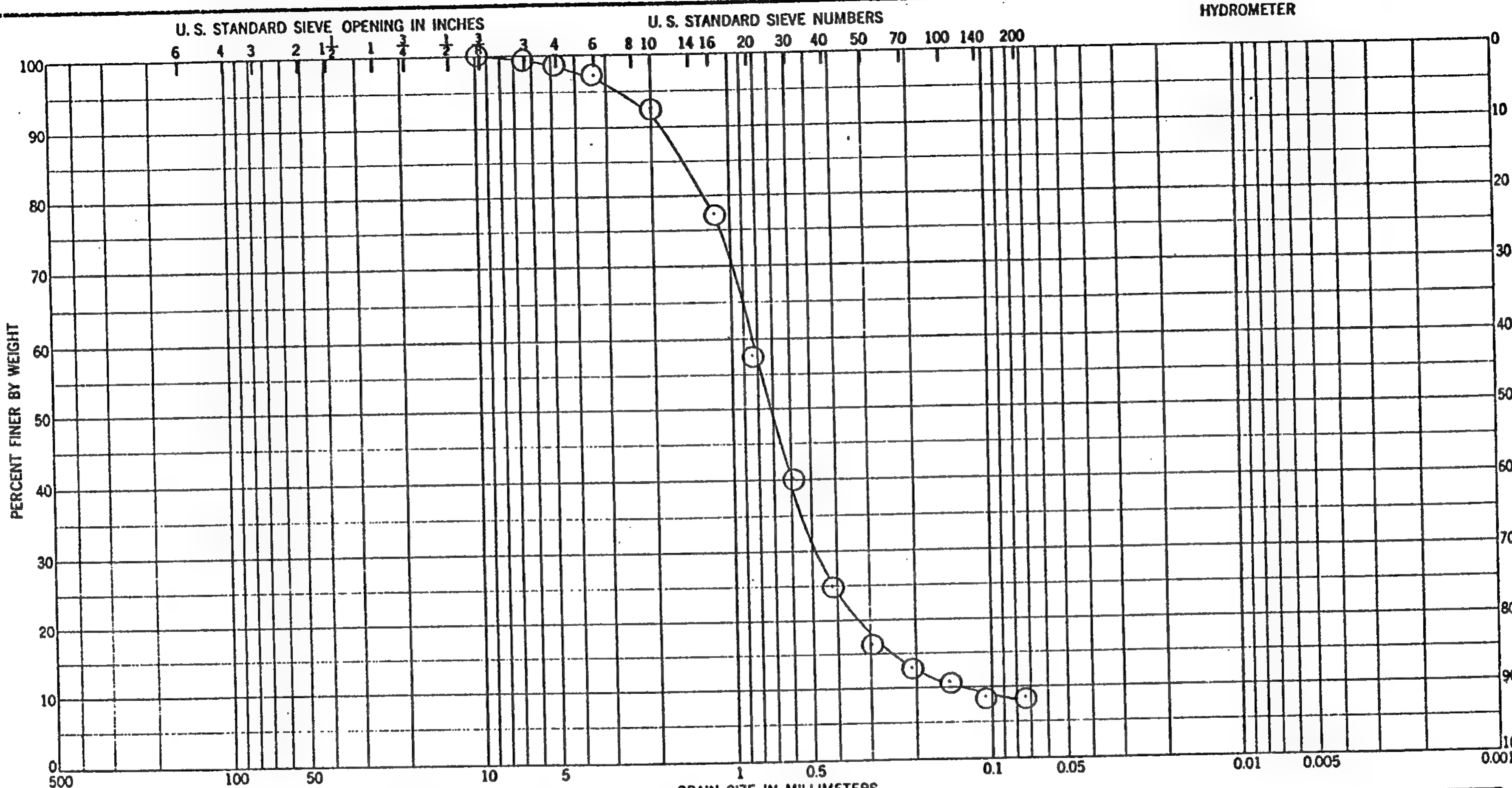
Boring No. 920

Date 11 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	14.0-15.5	SILTY SAND (SW-SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 921

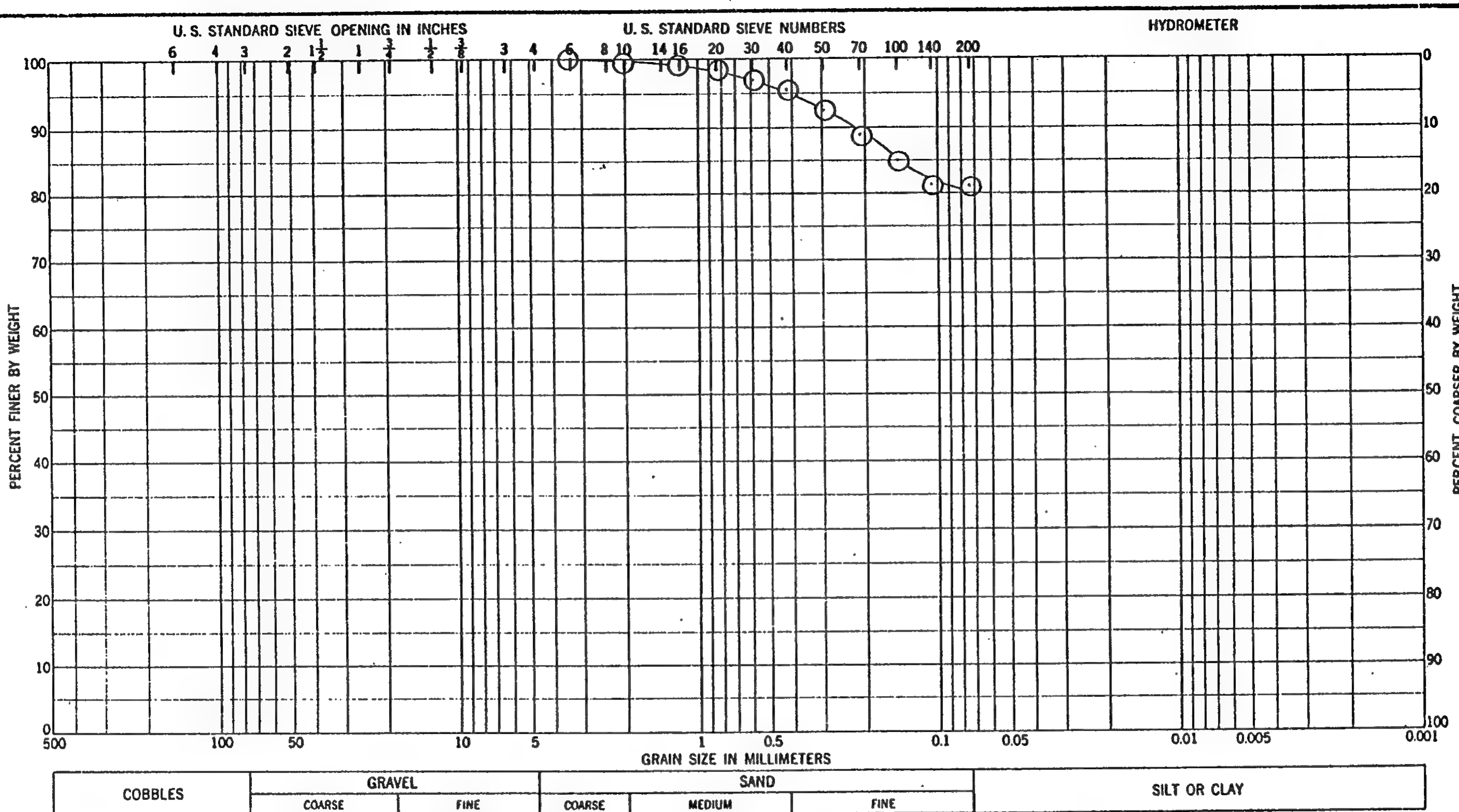
Date 3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A52

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
1	0.0-1.5	SANDY CLAY (CL) BROWN		31	15	16

Project: ROCKY MOUNTAIN ARSENAL

Area:

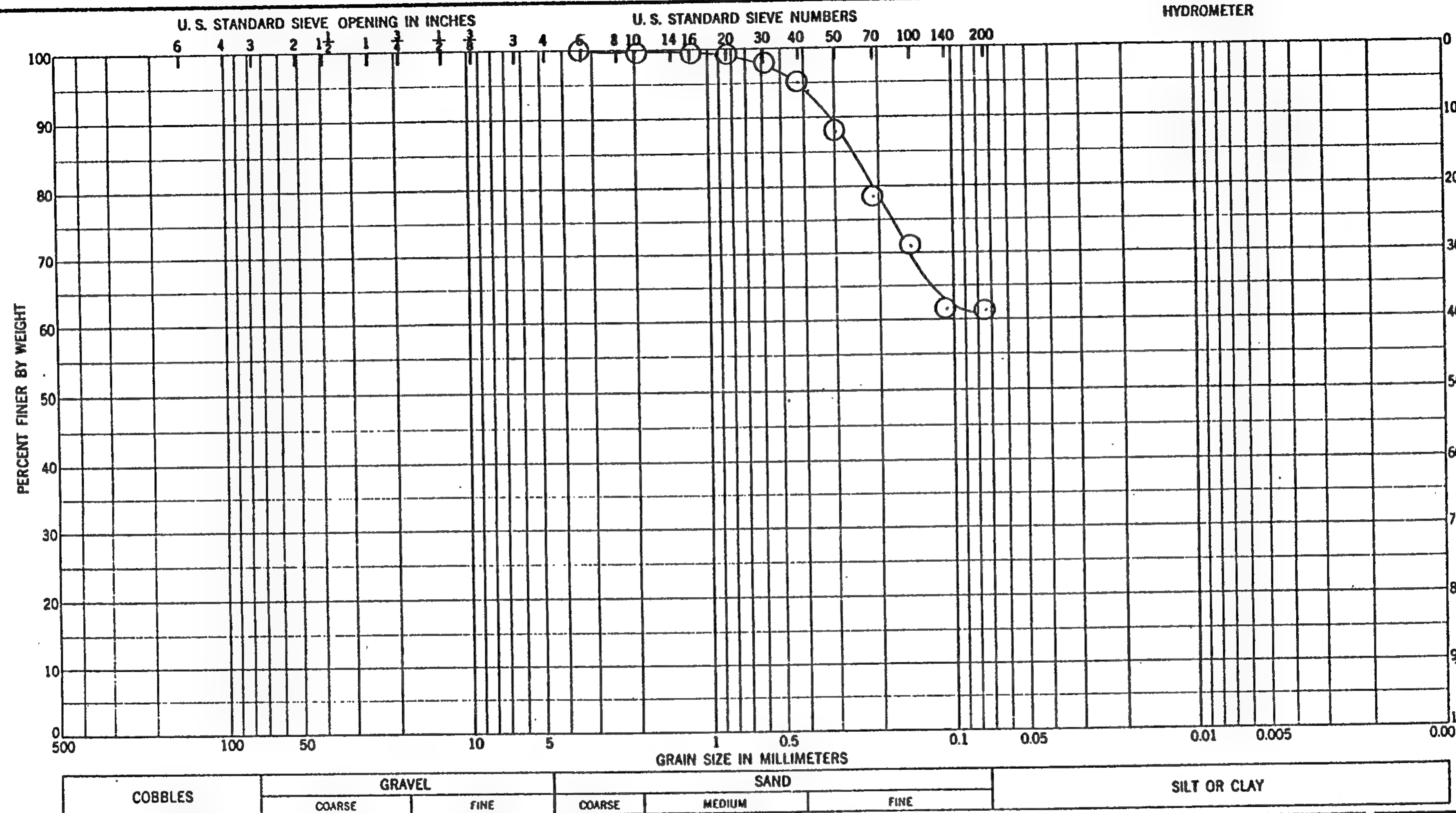
Boring No. 922

Date: 9 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
2	4.0-5.5	SANDY CLAY (CL) BROWN		25	13	12

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

Area

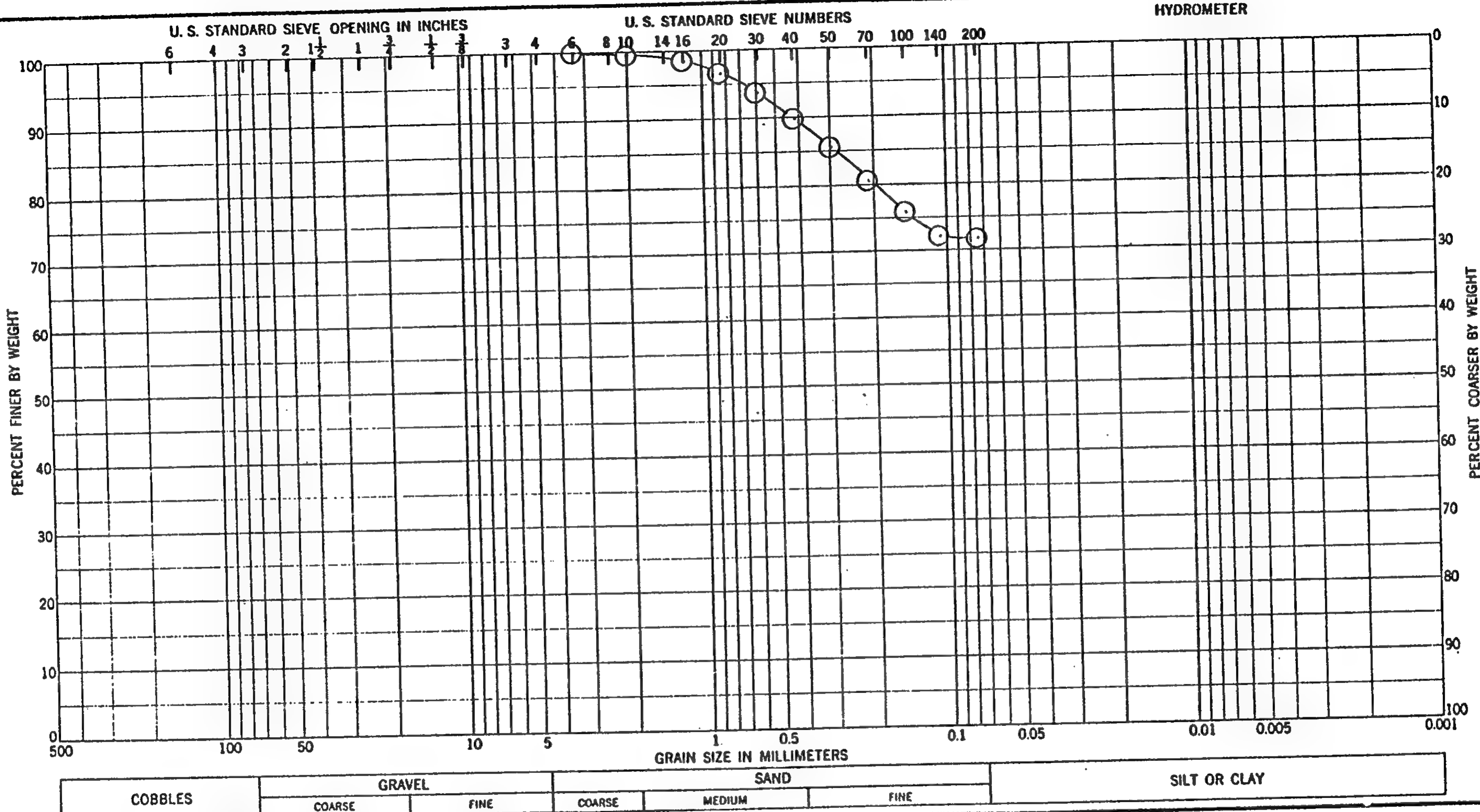
Boring No. 922

Date 9 JULY 79

Results of Sieve Analysis

Plate A54

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
3	9.0-10.5	SANDY CLAY (CL) BROWN		40	20	20

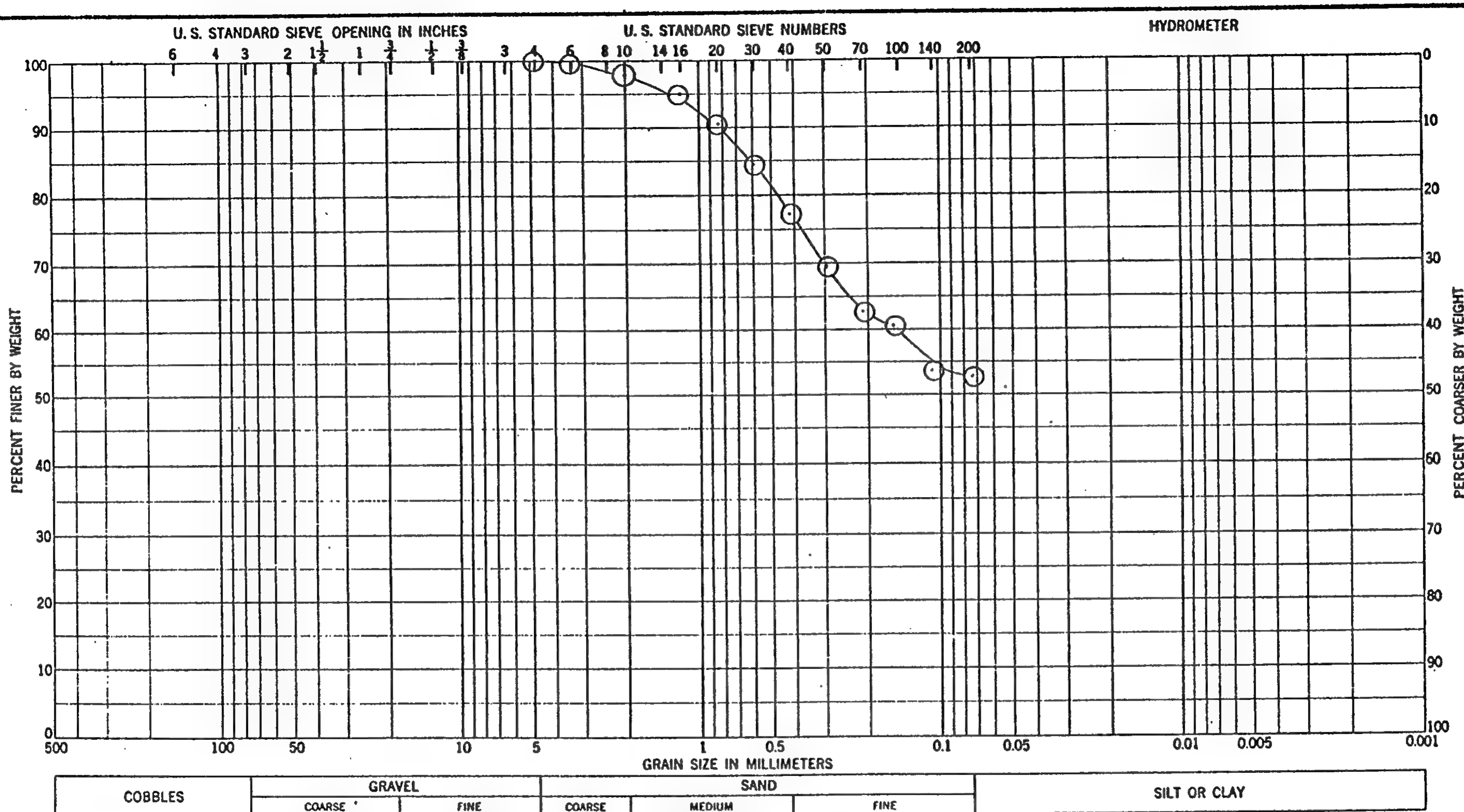
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	922
Date	9 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A55

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	14.0-15.5	SANDY CLAY (CL) TAN		34	12	22

Project ROCKY MOUNTAIN ARSENAL

Area

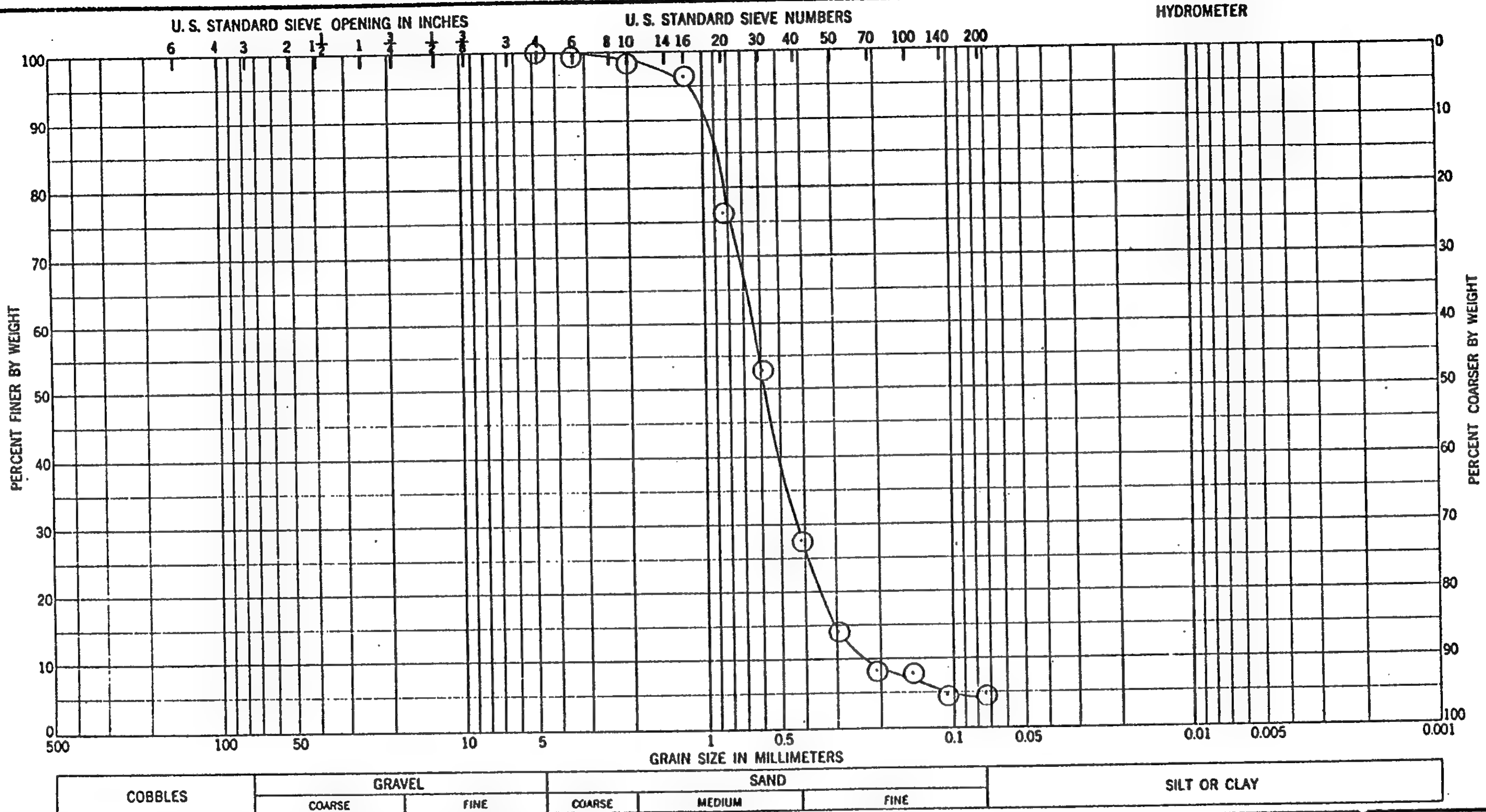
Boring No. 922

Date 3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	19.0-20.5	SAND (SP) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 922

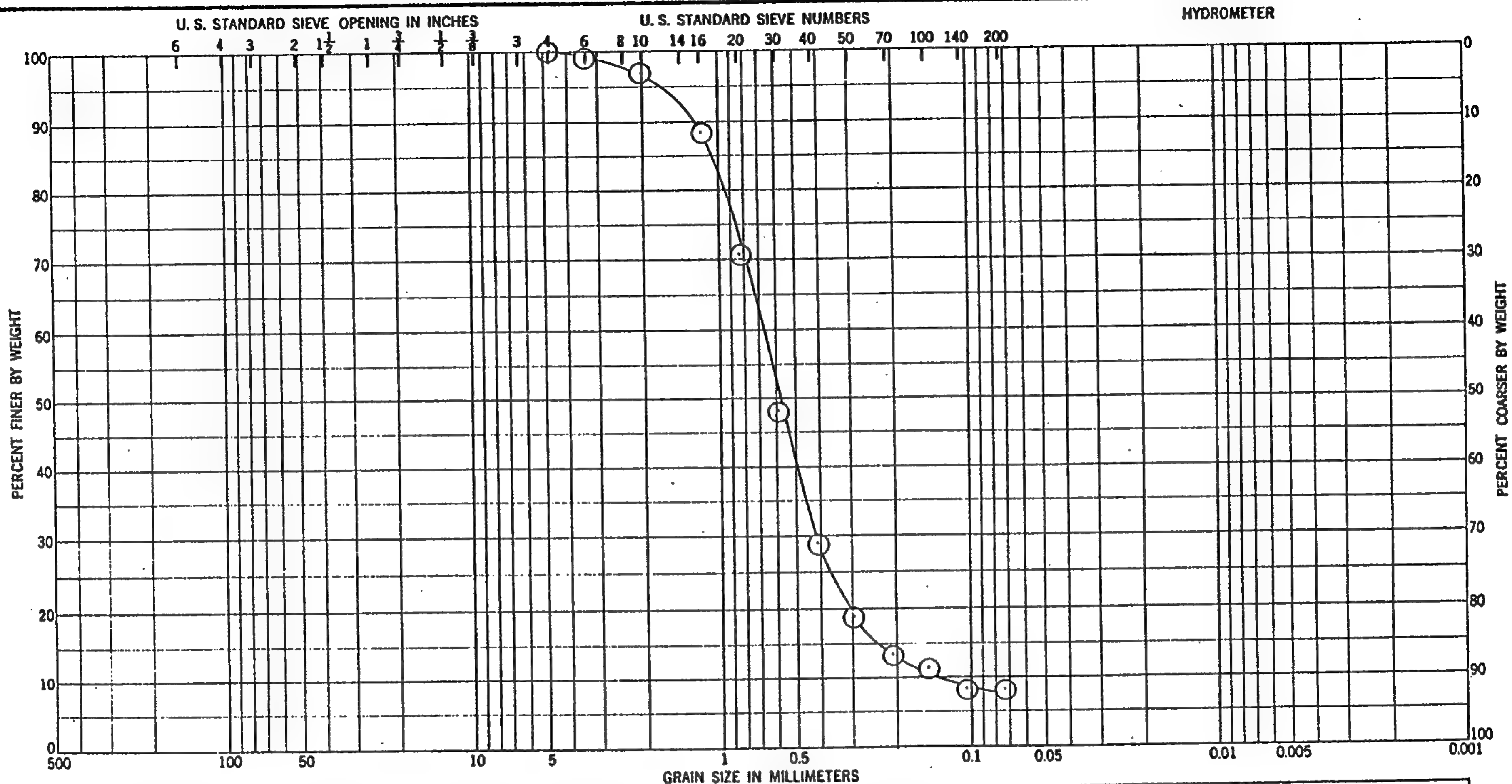
Date 2 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A57



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	24.0-25.0	SILTY SAND (SP-SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 922

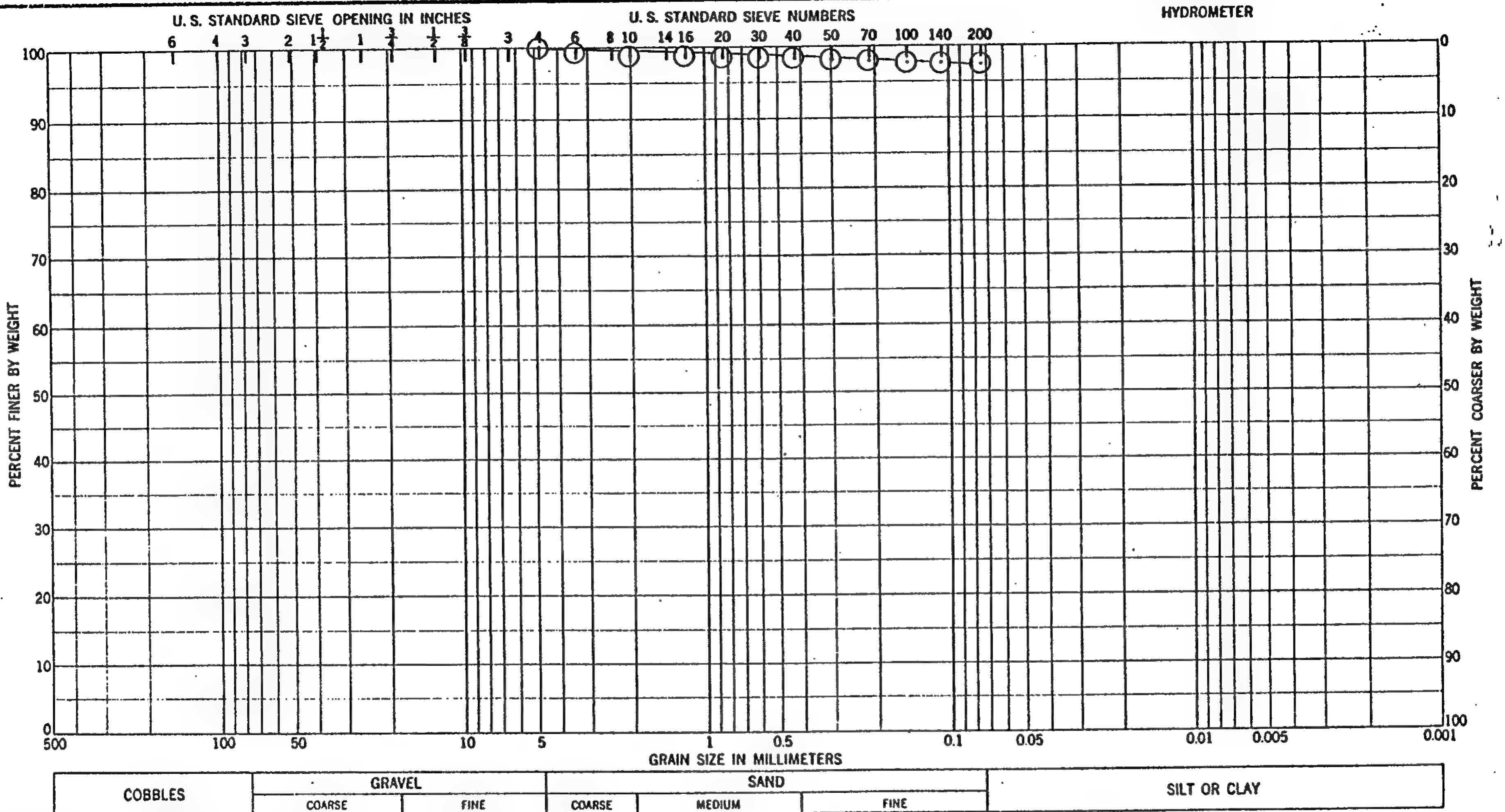
Date 10 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A58



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	29.0-30.5	CLAY (CH) BROWN		73	37	36

Project: ROCKY MOUNTAIN ARSENAL

Area:

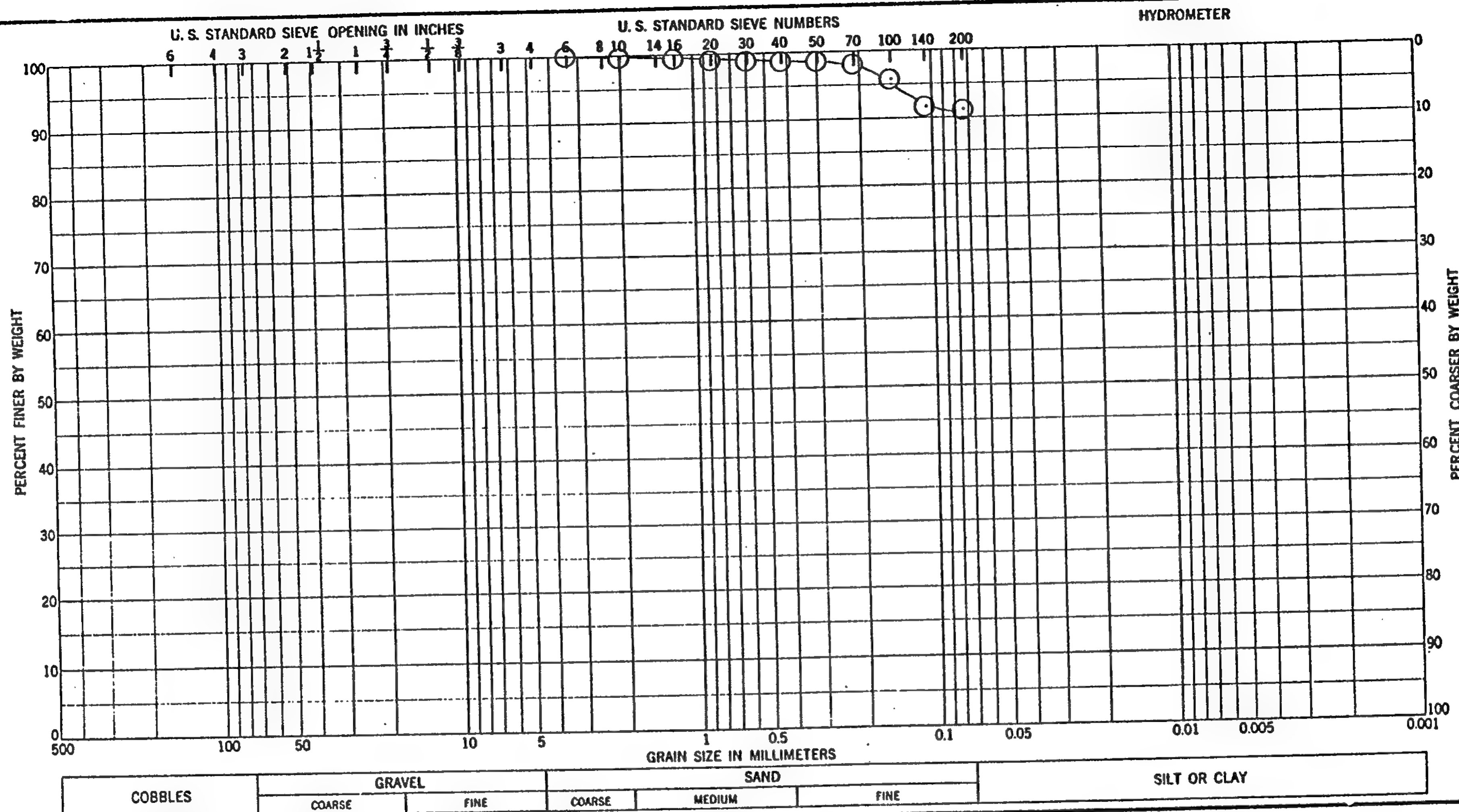
Boring No.: 922

Date: 11 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	CLAY (CH) WITH SAND BROWN		62	26	36

Project: ROCKY MOUNTAIN ARSENAL

Area:

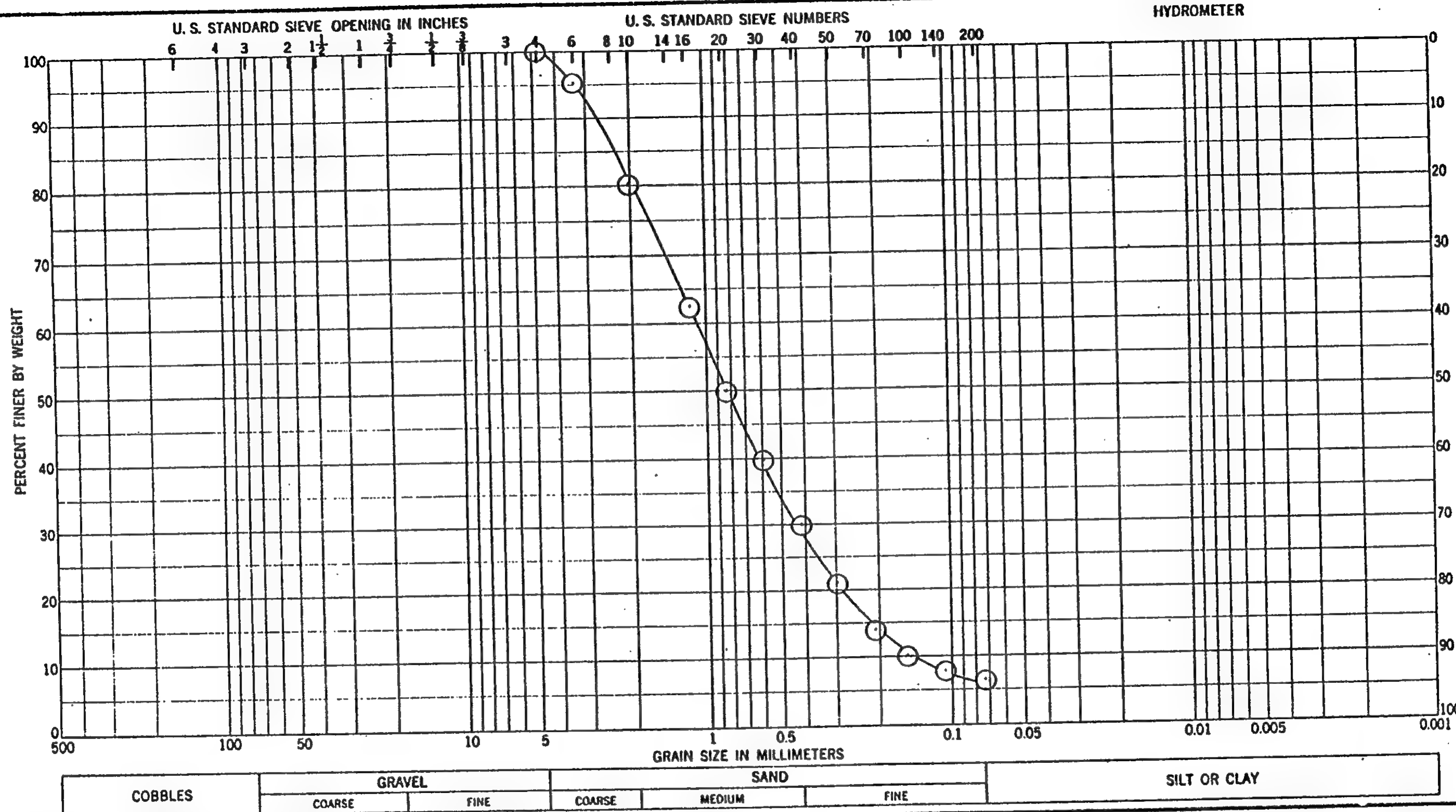
Boring No. 922

Date: 10 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
9	39.0-40.5	CLAYEY SAND (SW-SC) TAN		52	21	31

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

Area

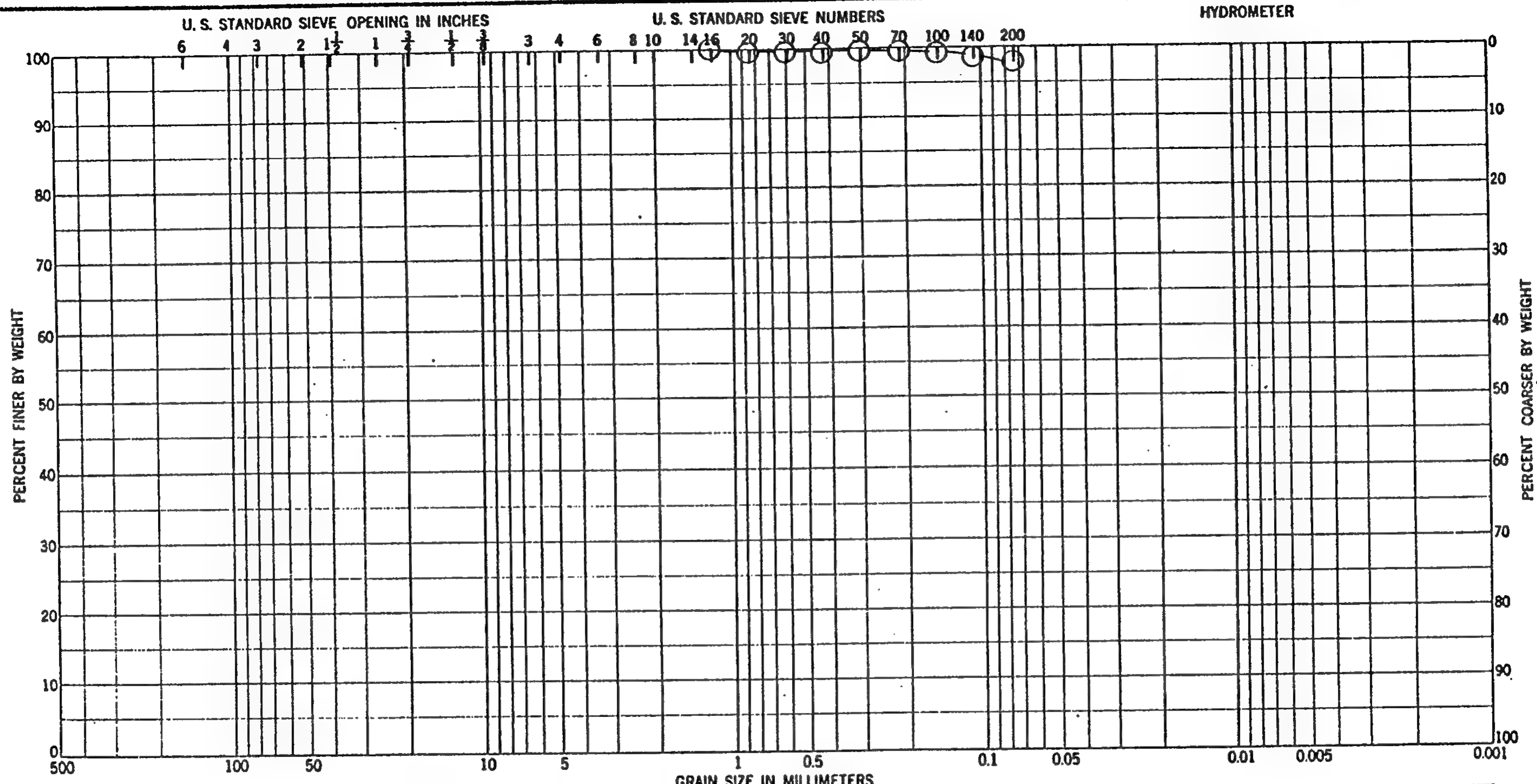
Boring No. 922

Date 11 JULY 79

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A61



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
10	44.0-45.5	CLAY (CL) GRAY		46	18	28

Project: ROCKY MOUNTAIN ARSENAL

Area:

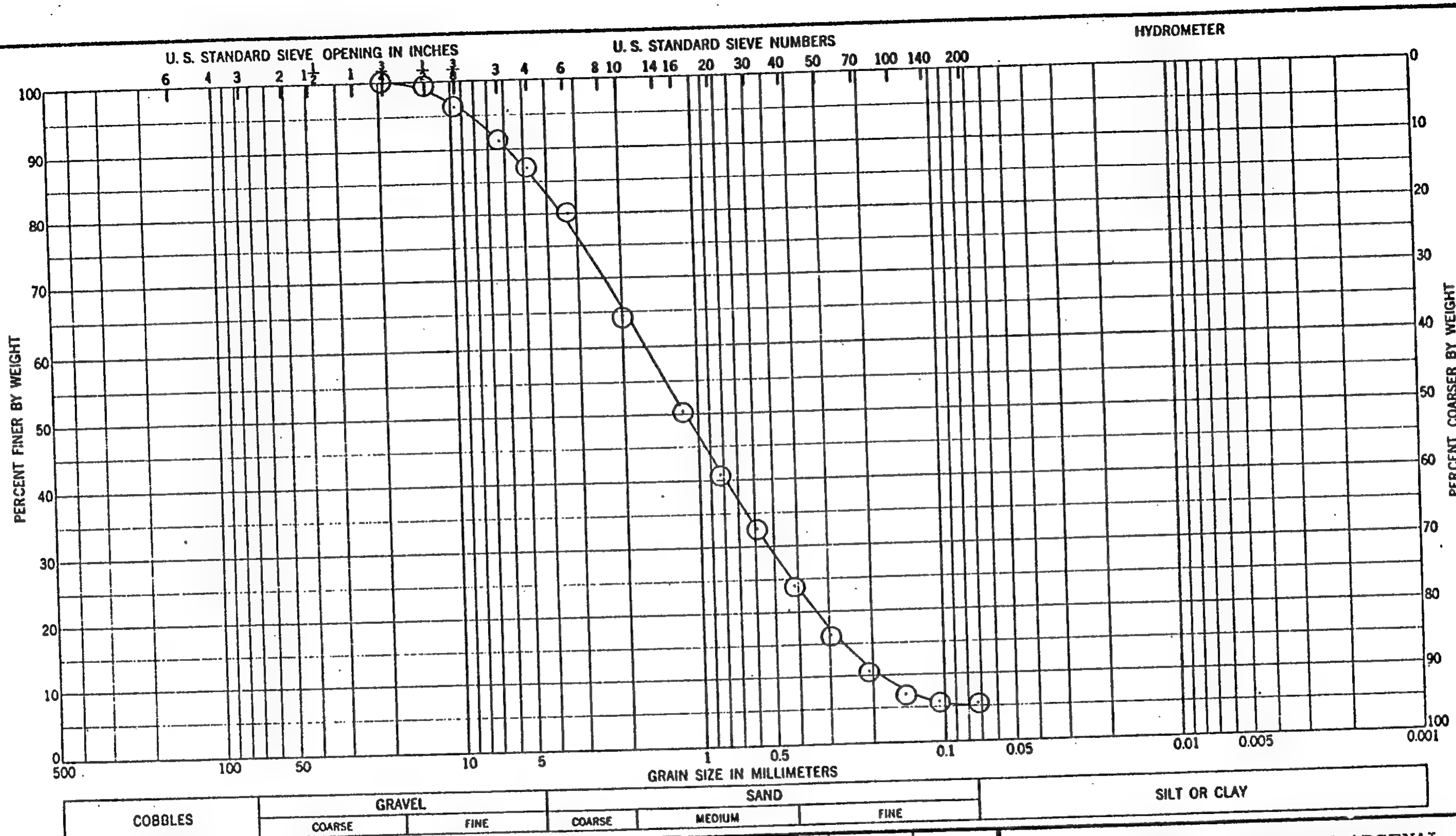
Boring No. 922

Date: 9 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
10	45.0-46.5	GRAVELLY SILTY SAND (SP-SM) TAN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No.: 923

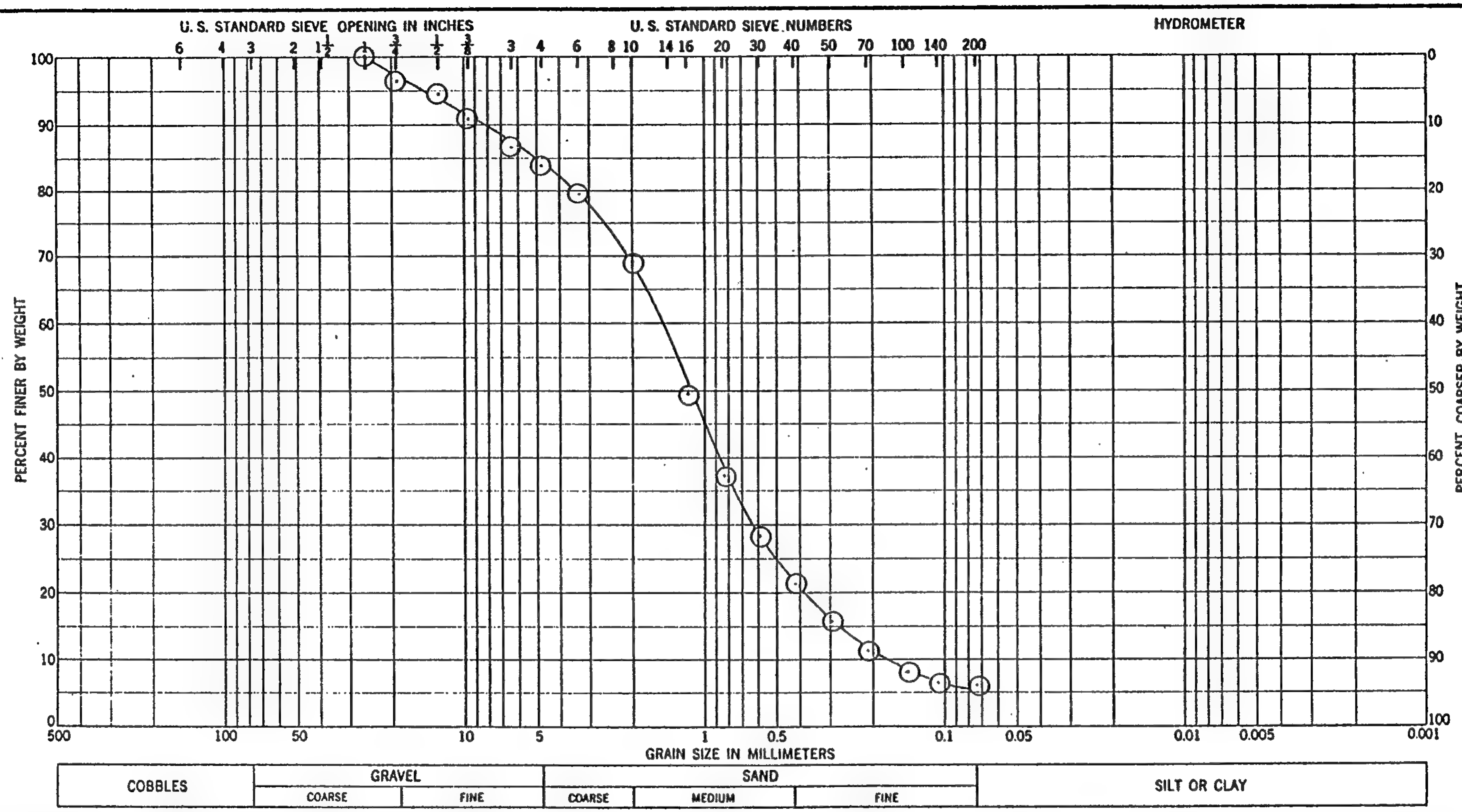
Date: 11 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A63



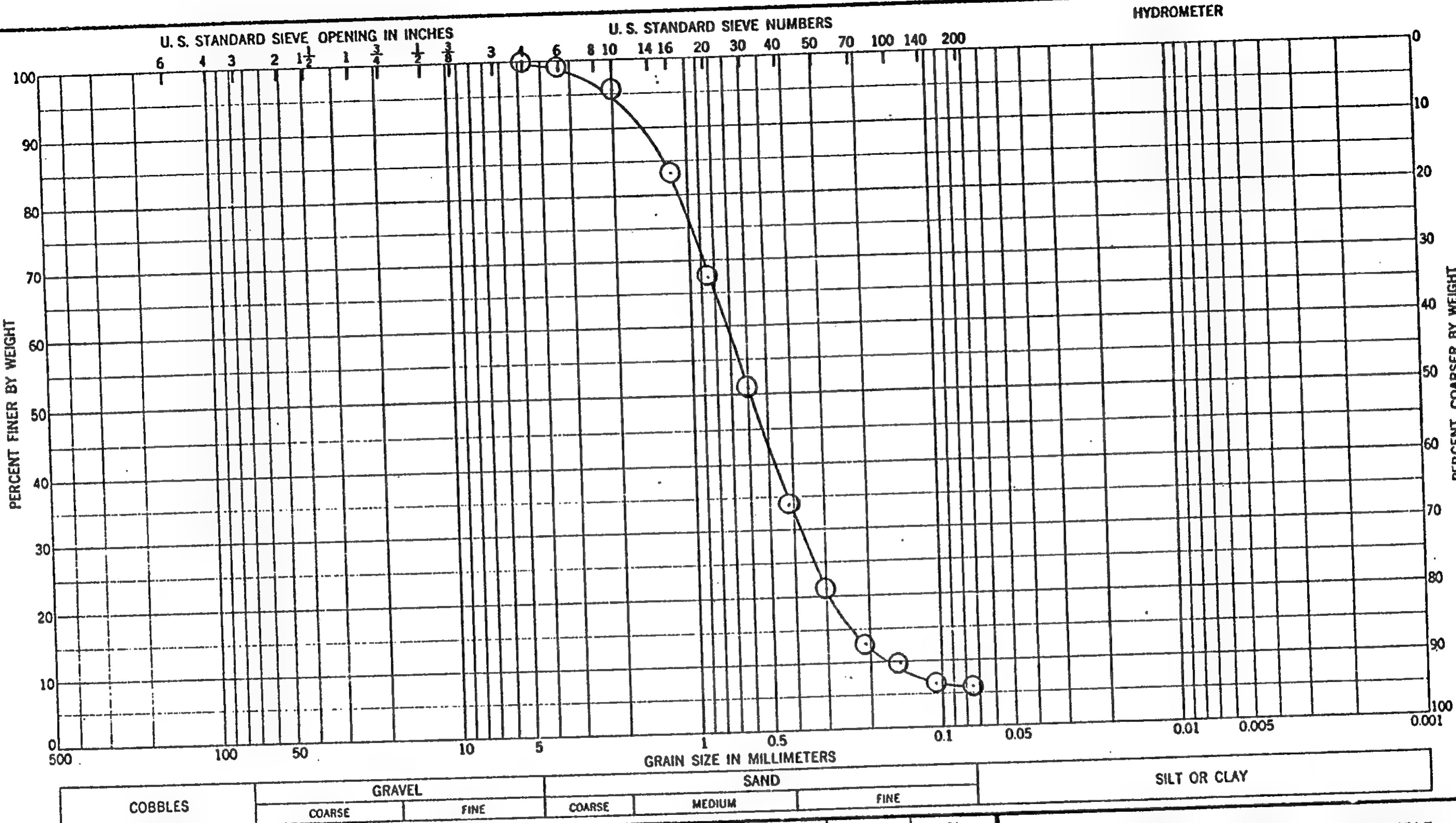
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	GRAVELLY SILTY SAND (SW-SM) BROWN				

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	924
Date	11 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	24.0-25.5	SILTY SAND (SP-SM) TAN				

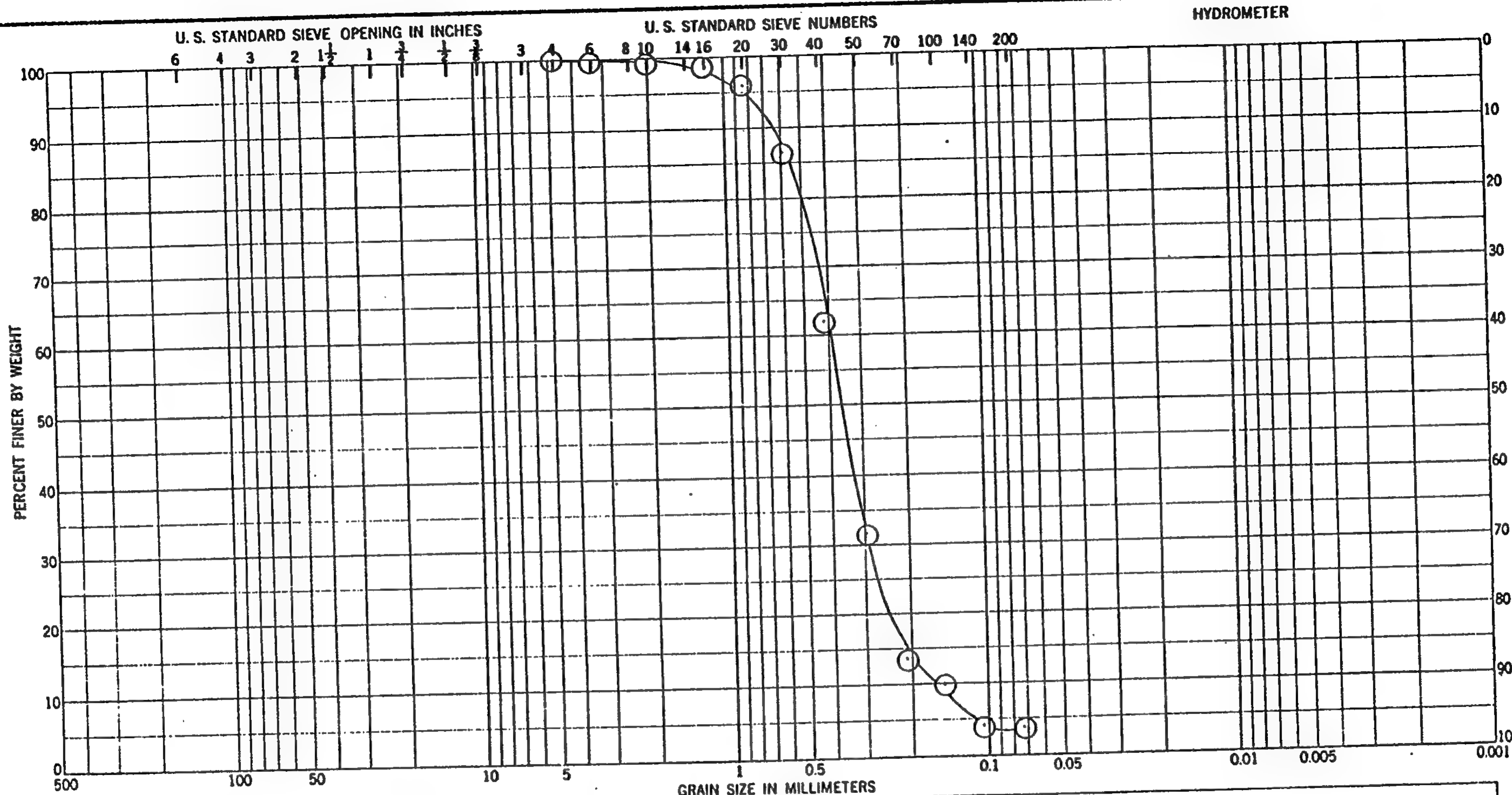
Project: ROCKY MOUNTAIN ARSENAL
Area:
Boring No. 925
Date: 3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A65

ENG FORM 1 MAY 63 2087



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	SAND (SP) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 926

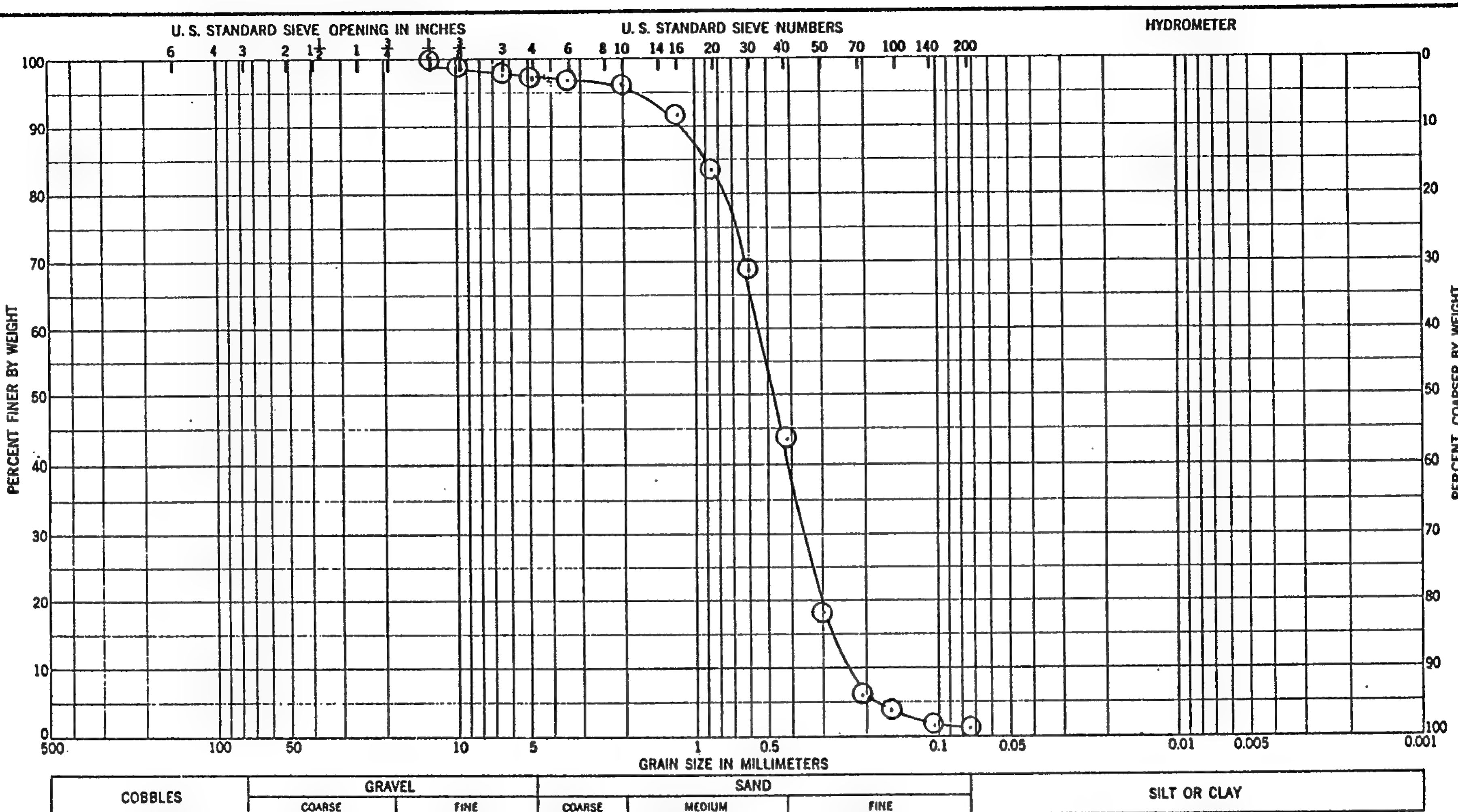
Date 3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A66



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	SAND (SP) TAN				

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

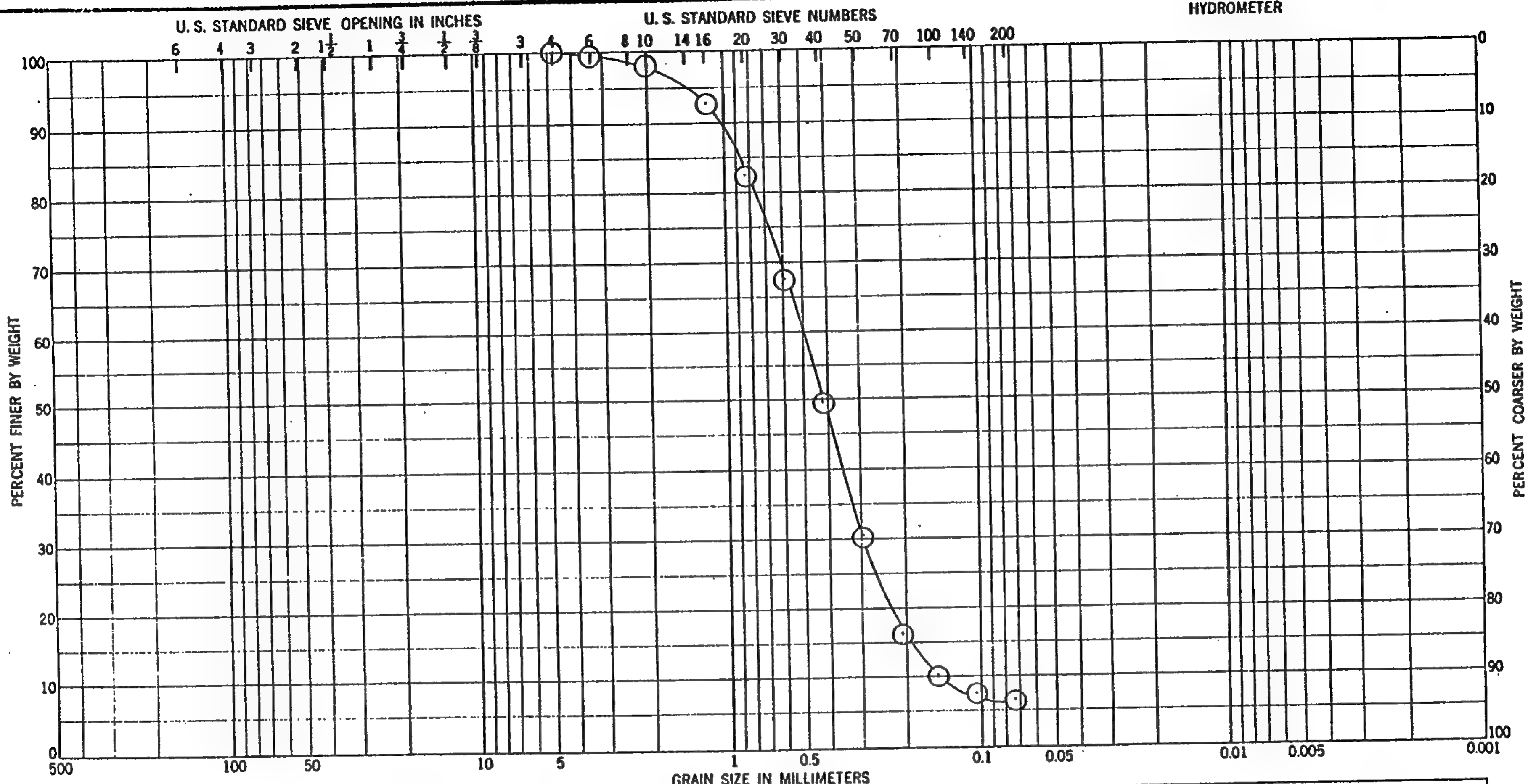
Area

Boring No. 928

Date 10 JULY 79

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	19.0-20.5	SILTY SAND (SP-SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 929

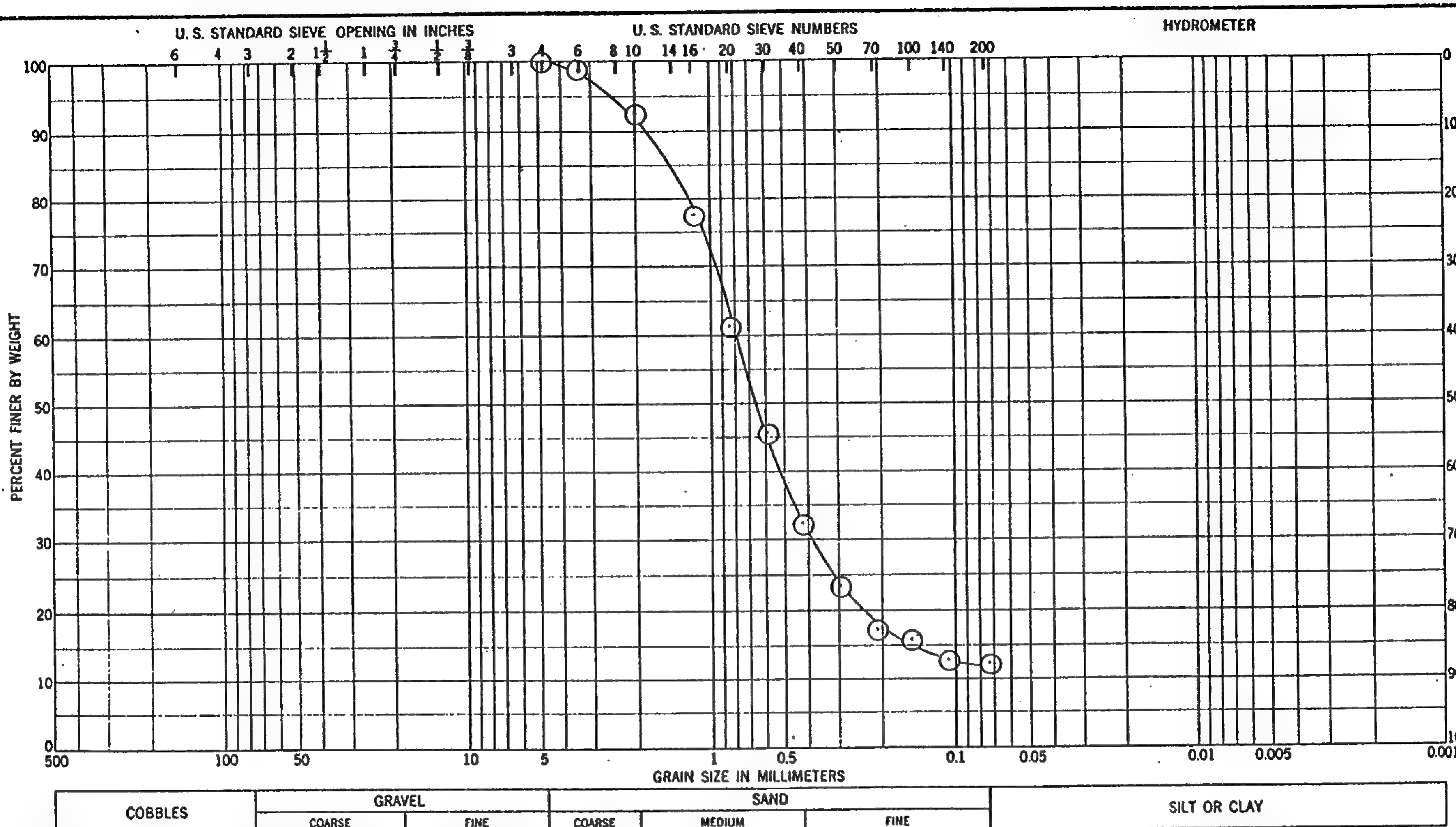
Date 10 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A68



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	14.0-15.5	CLAYEY SAND (SC) TAN		53	19	34

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 932

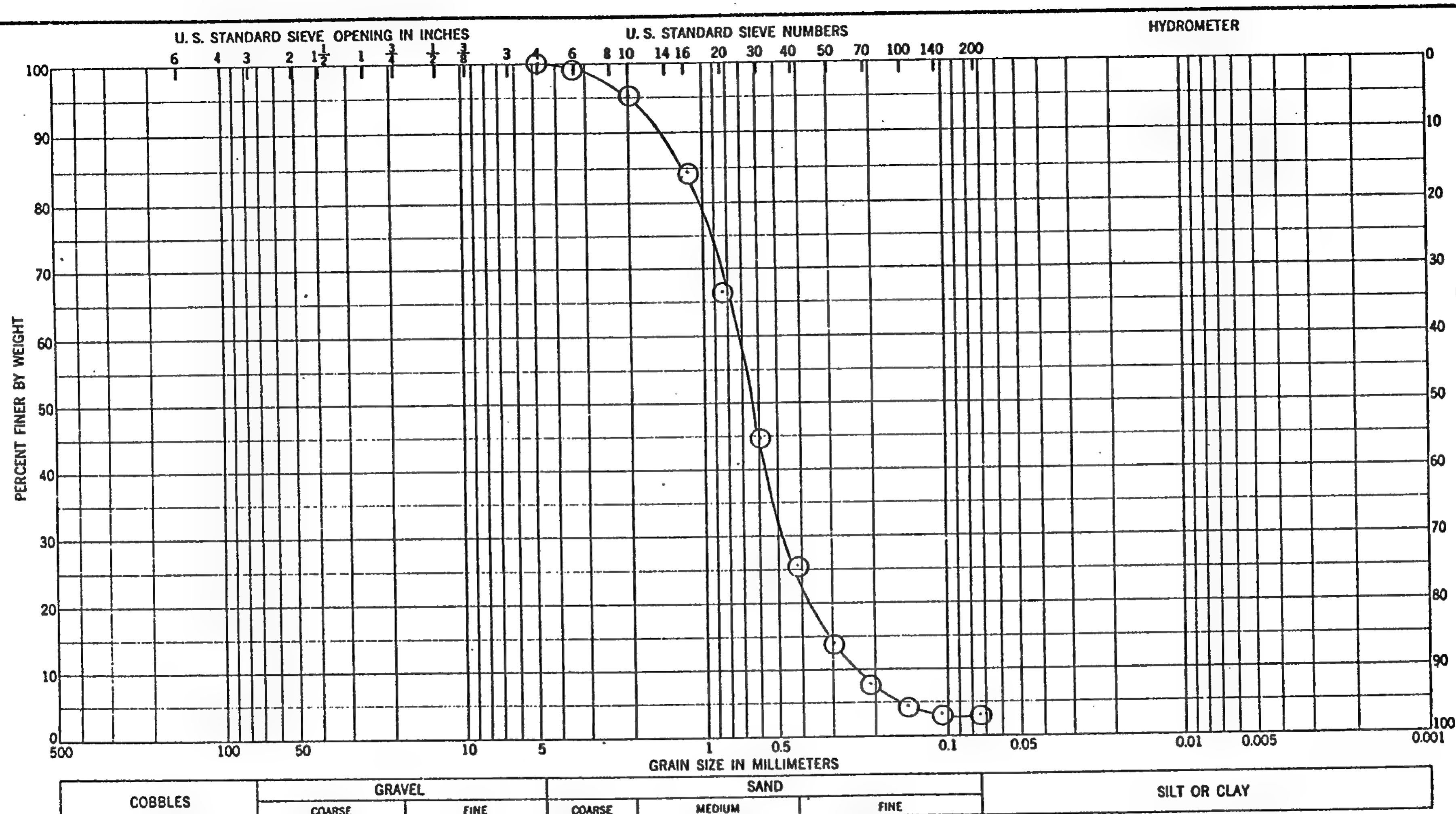
Date 3 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A69



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	24.0-25.5	SAND (SP) TAN				

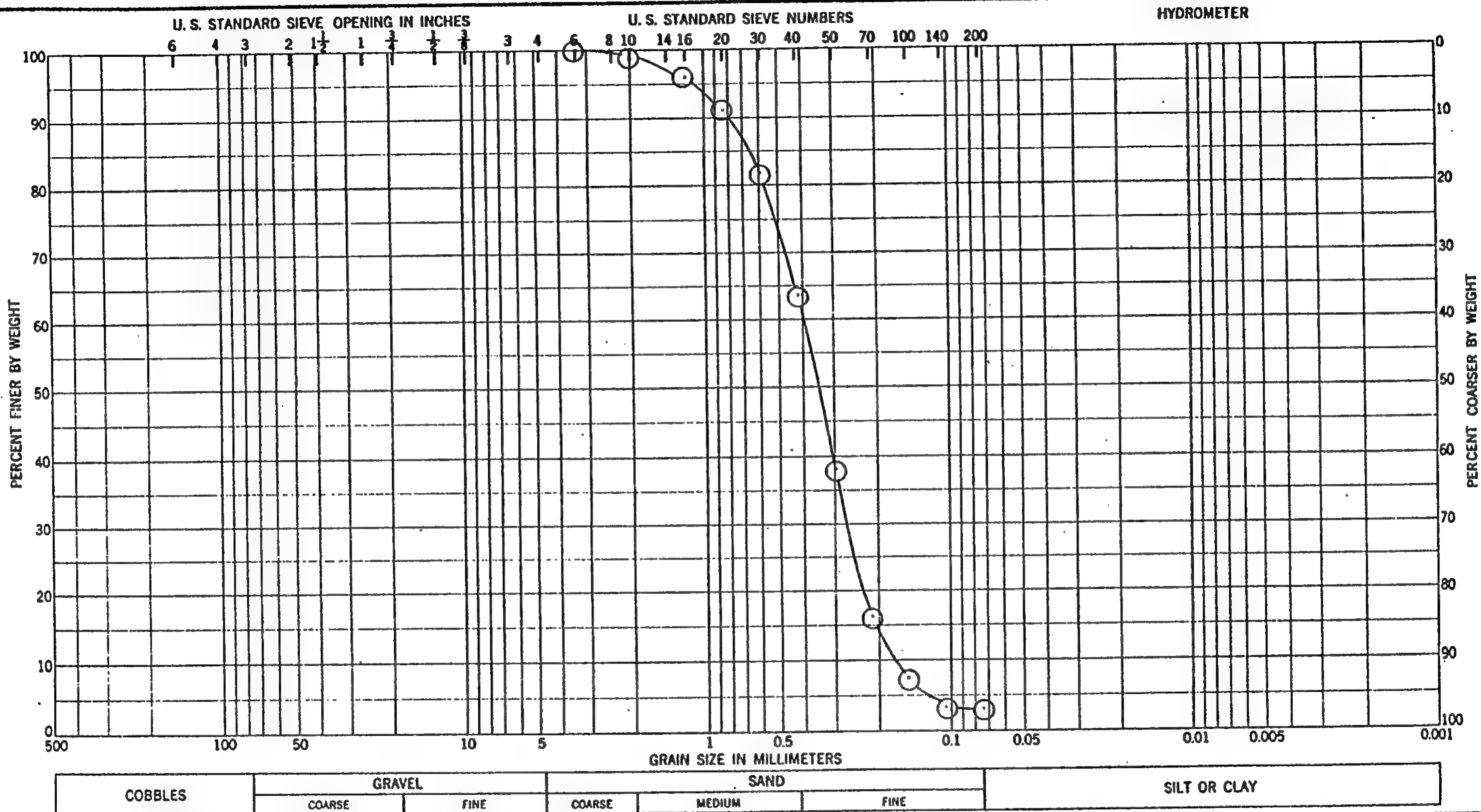
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	933
Date	3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A70



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	29.0-30.5	SAND (SP) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 934

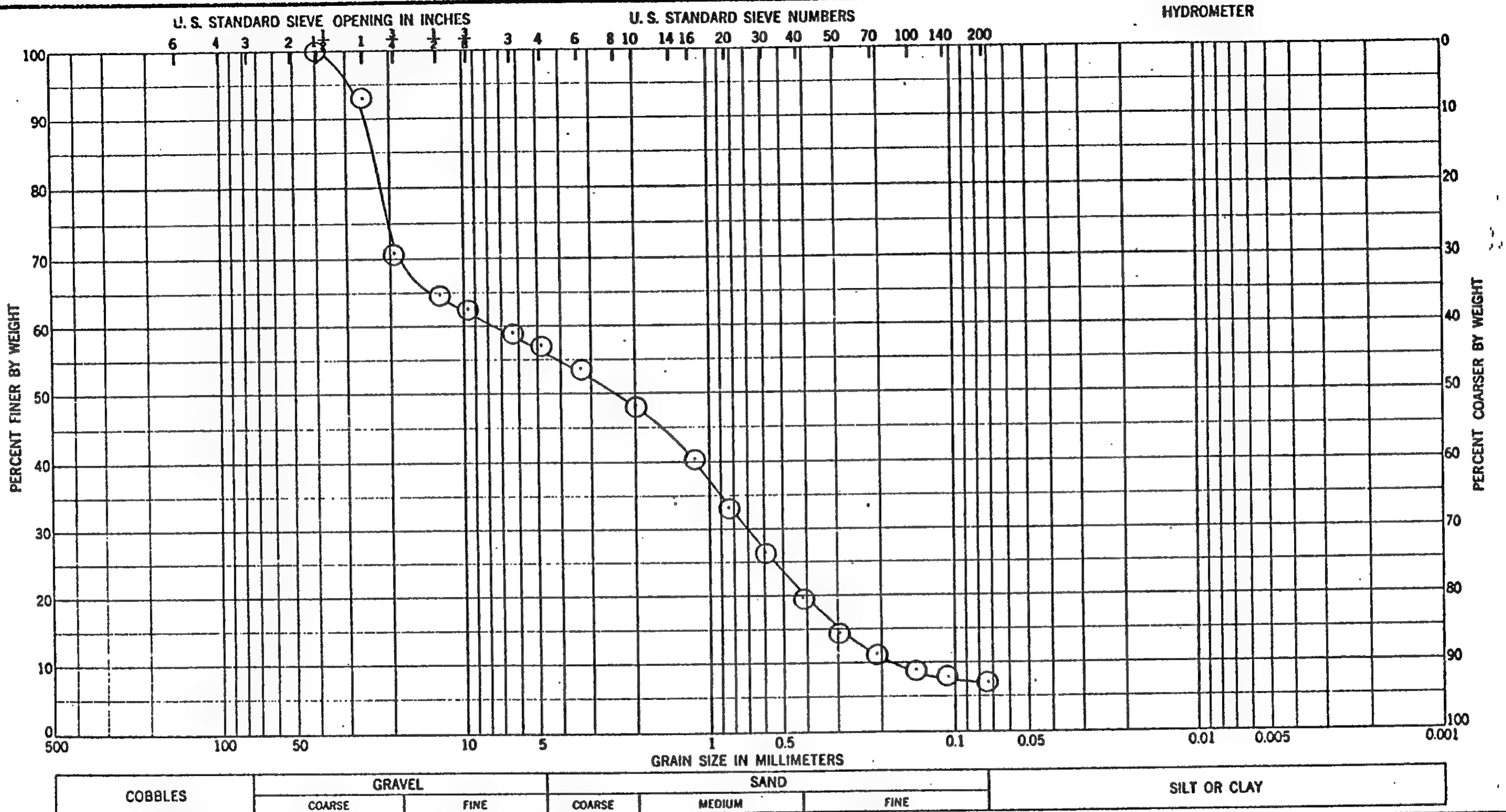
Date 3JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A71.



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	19.0-20.5	GRAVELLY SILTY SAND (SP-SM) BROWN				

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

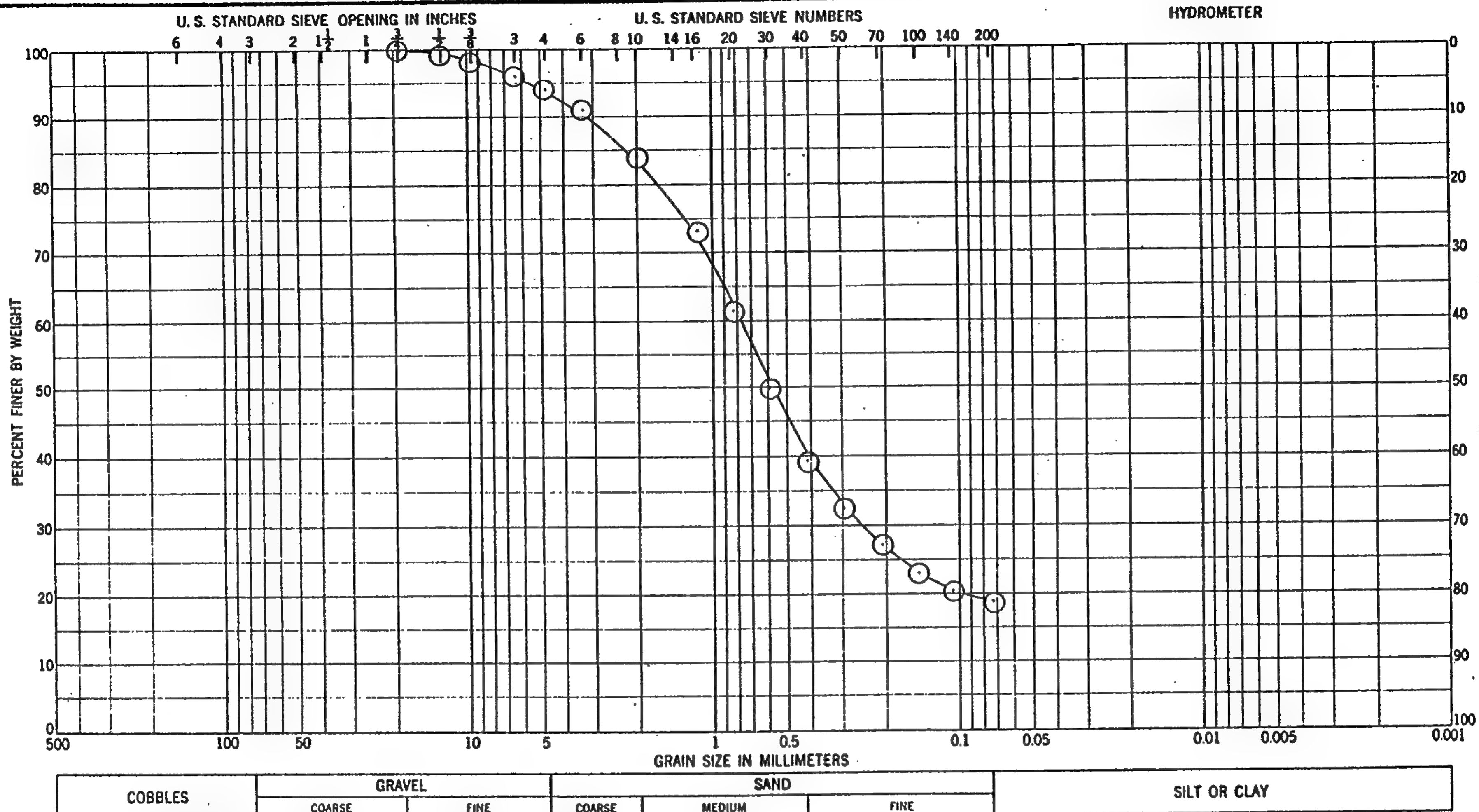
Area

Boring No. 935

Date 10 JULY 79

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	19.0-20.5	CLAYEY SAND (SC) WITH GRAVEL BROWN		41	21	20

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No.: 936

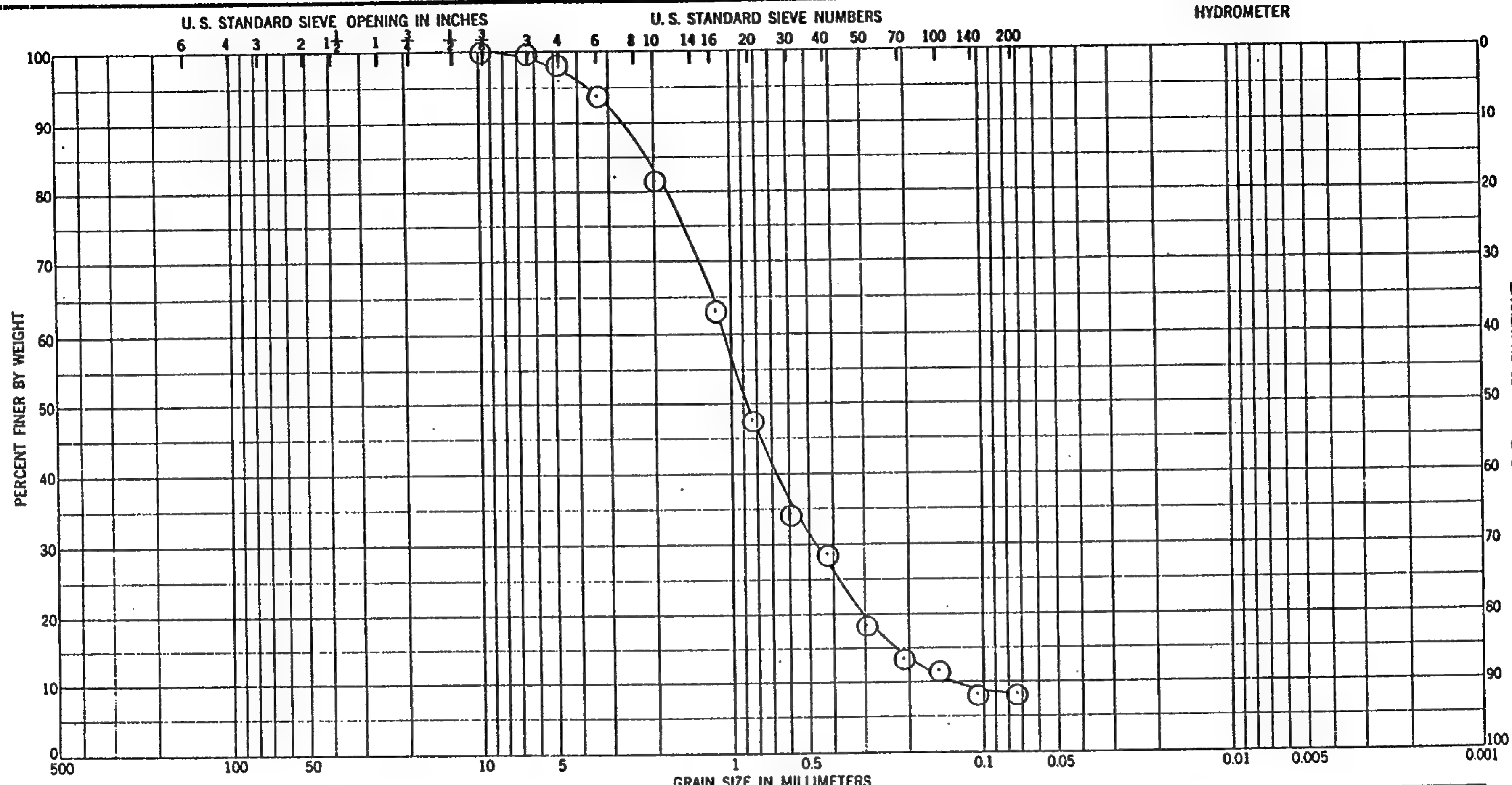
Date: 11 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A73



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	30.0-31.5	SILTY SAND (SW-SM) BROWN				

Project ROCKY MOUNTAIN ARSENAL

Area

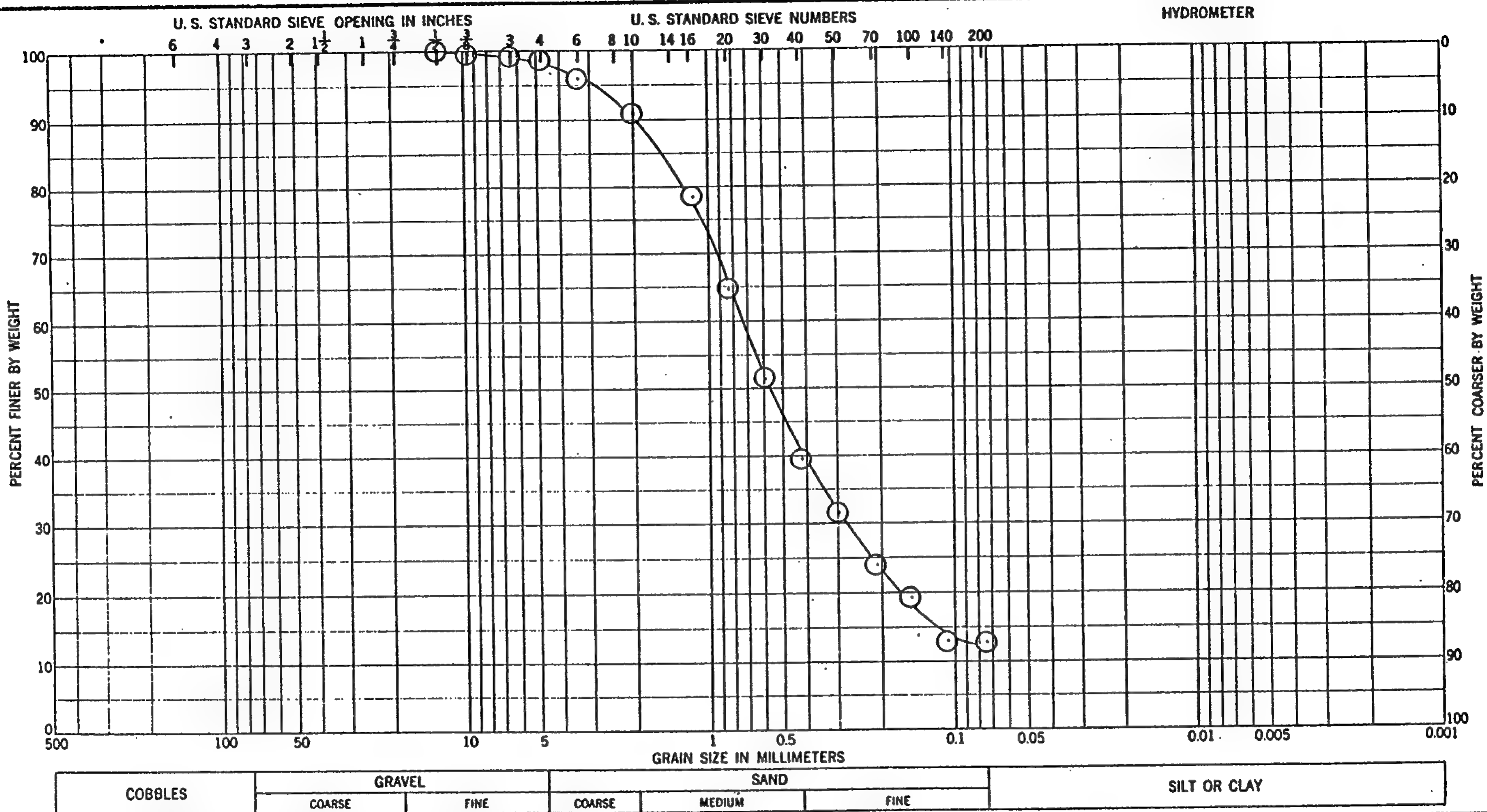
Boring No. 937

Date 2 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	SILTY SAND (SM) TAN				

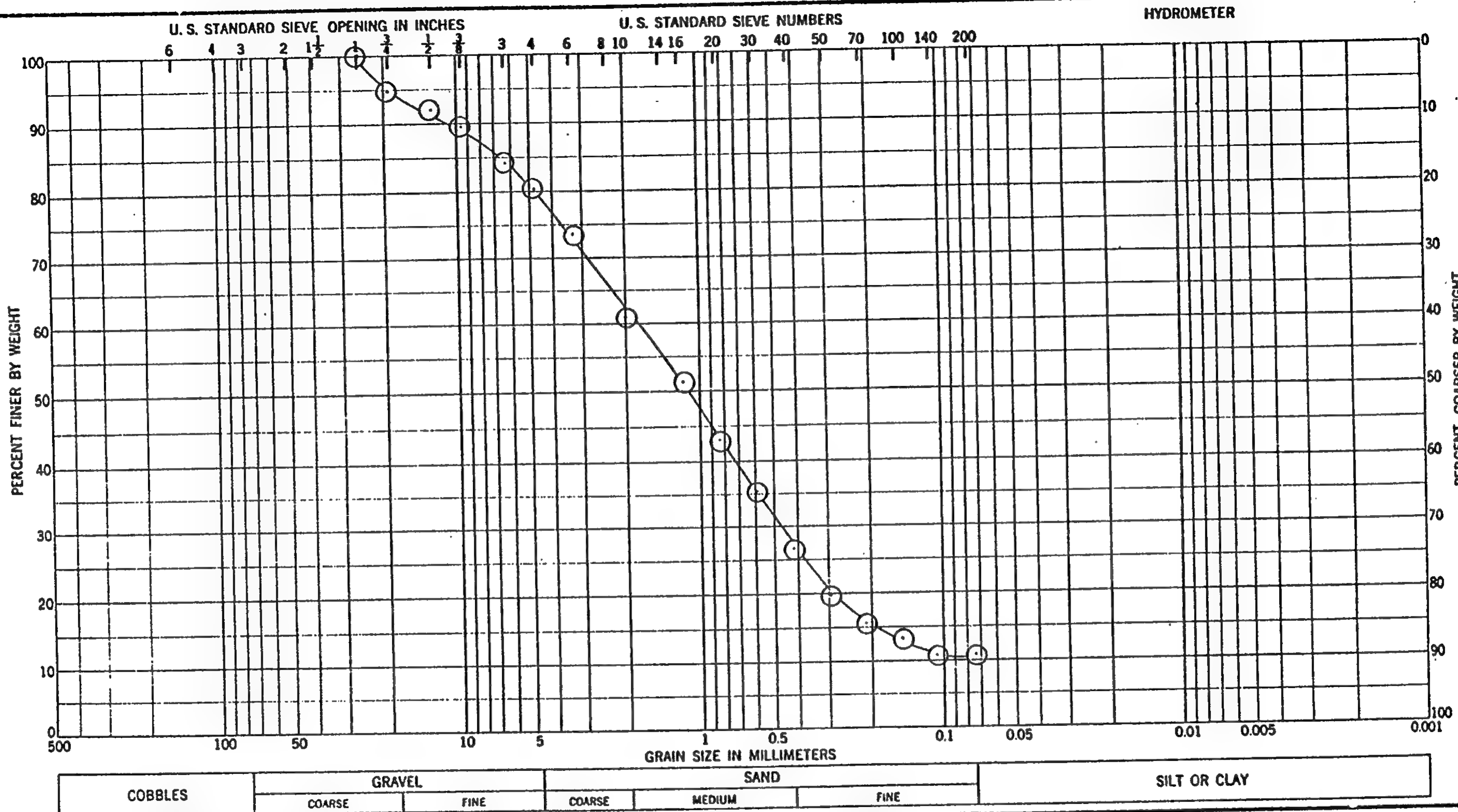
GRADATION CURVES

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	938
Date	11 JULY 79

Results of Sieve Analysis

Plate A75

ENG FORM 1 MAY 63 2087



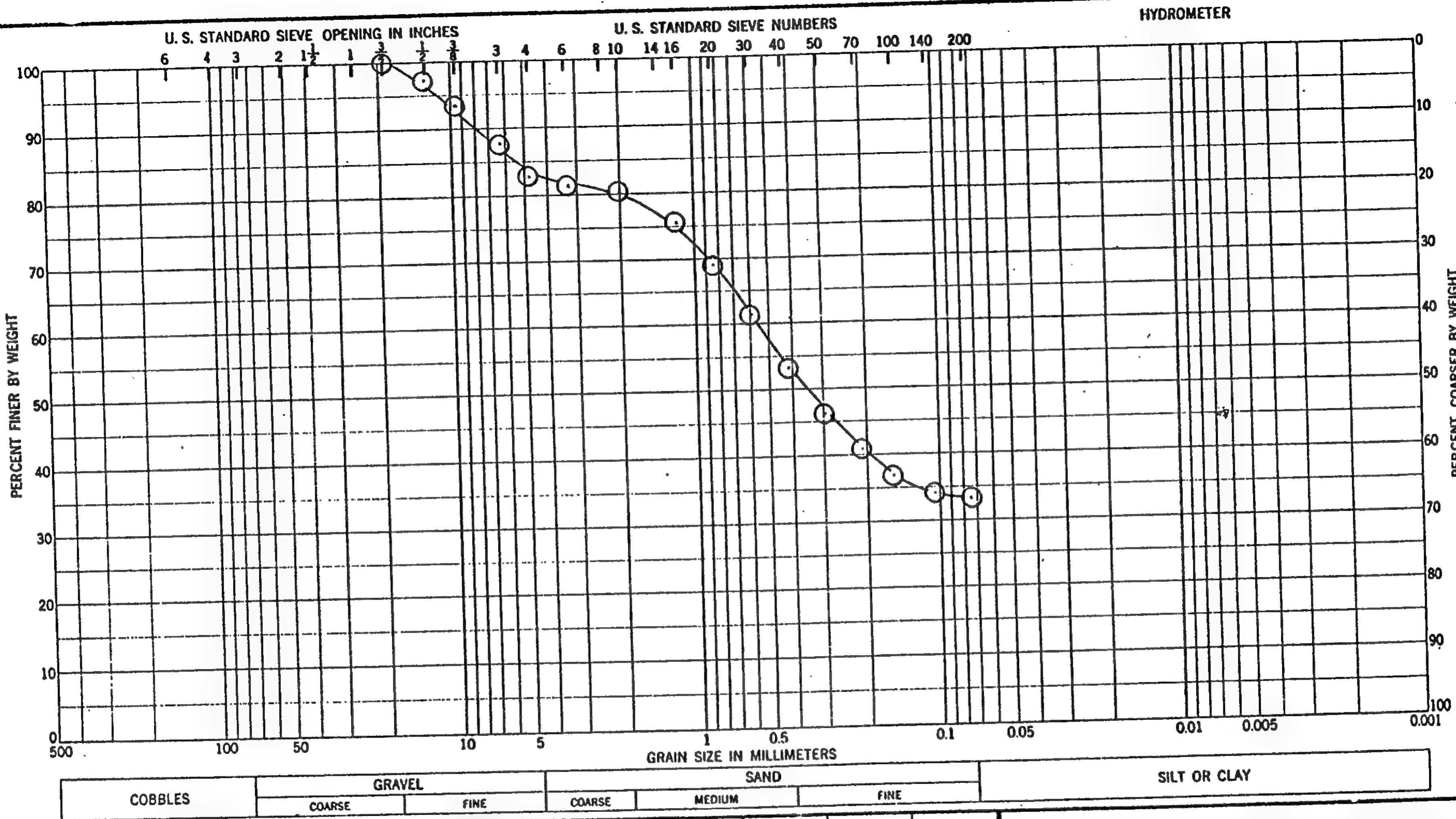
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	25.0-26.5	GRAVELLY SILTY SAND(SP-SM) BROWN				

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	939
Date	3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	GRAVELLY CLAYEY SAND (SC) BROWN		36	14	22

Project: ROCKY MOUNTAIN ARSENAL

Area:

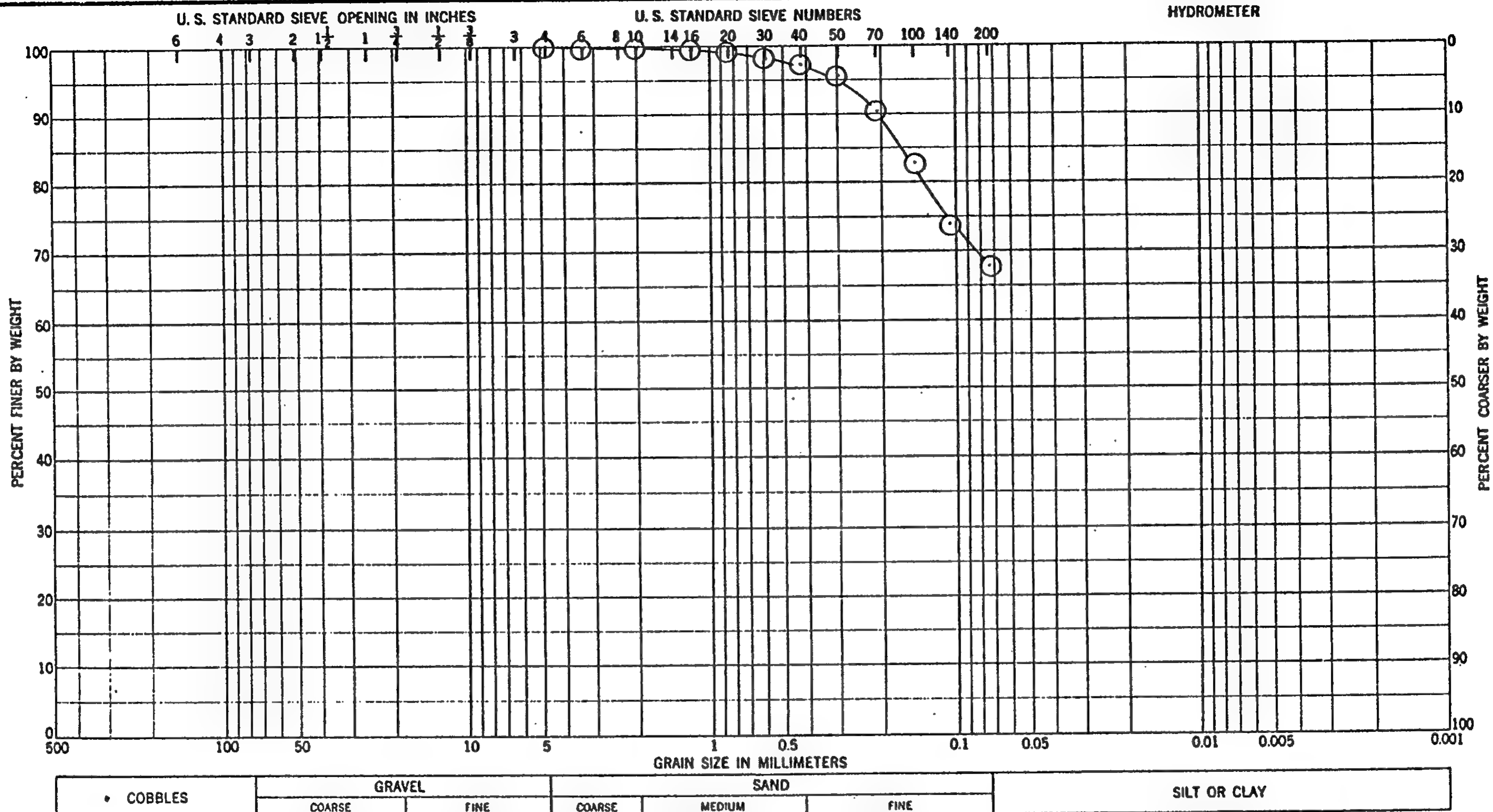
Boring No. 940

Date: 9 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
3	10.0-11.5	SANDY CLAY (CL) BROWN		36	16	20

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 941

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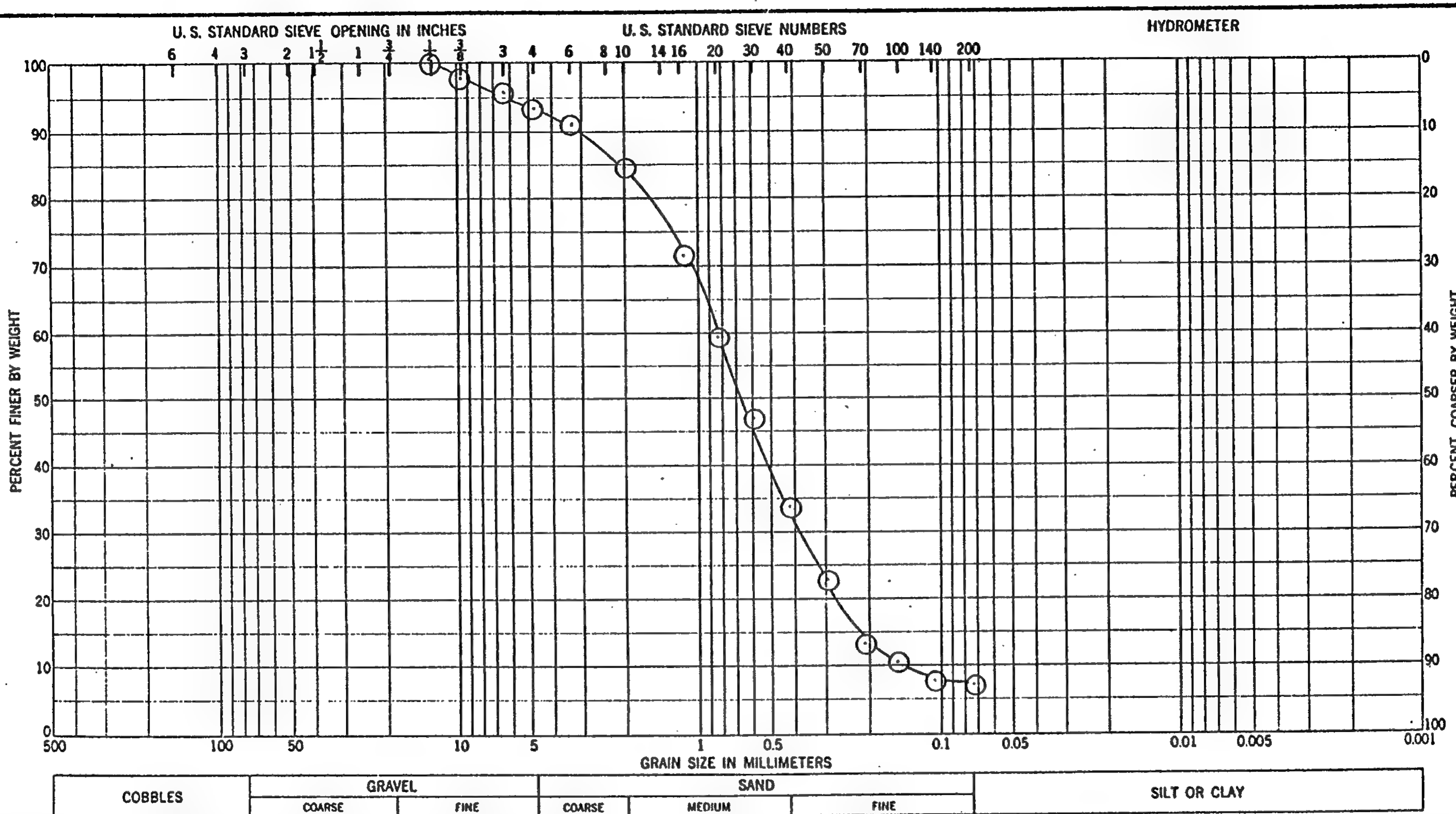
Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A78



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	CLAYEY SAND (SP-SC) WITH GRAVEL TAN		48	18	30

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	942
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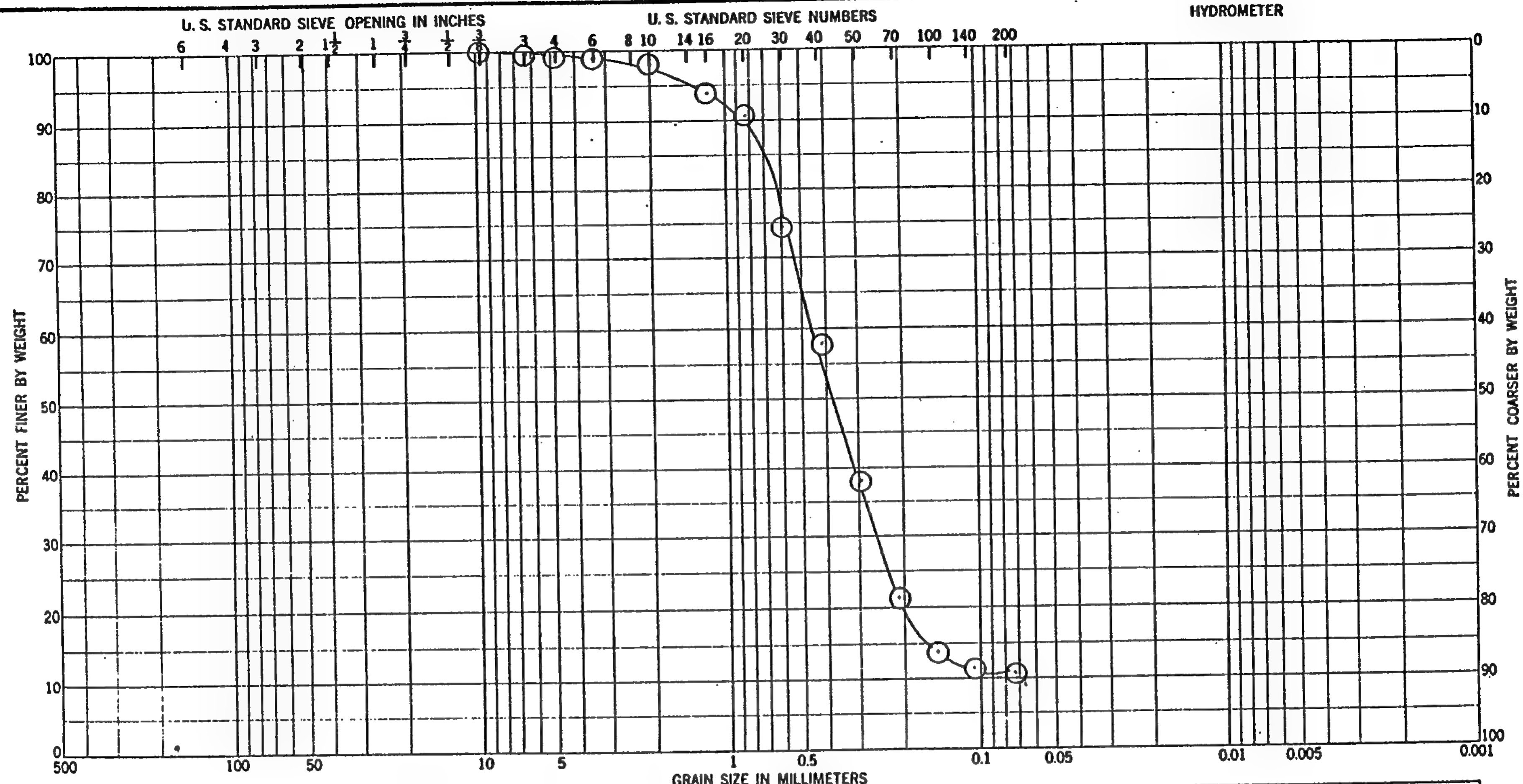
GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A79



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	30.0-31.5	CLAYEY SAND (SW-SC) BROWN		30	16	14

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 943

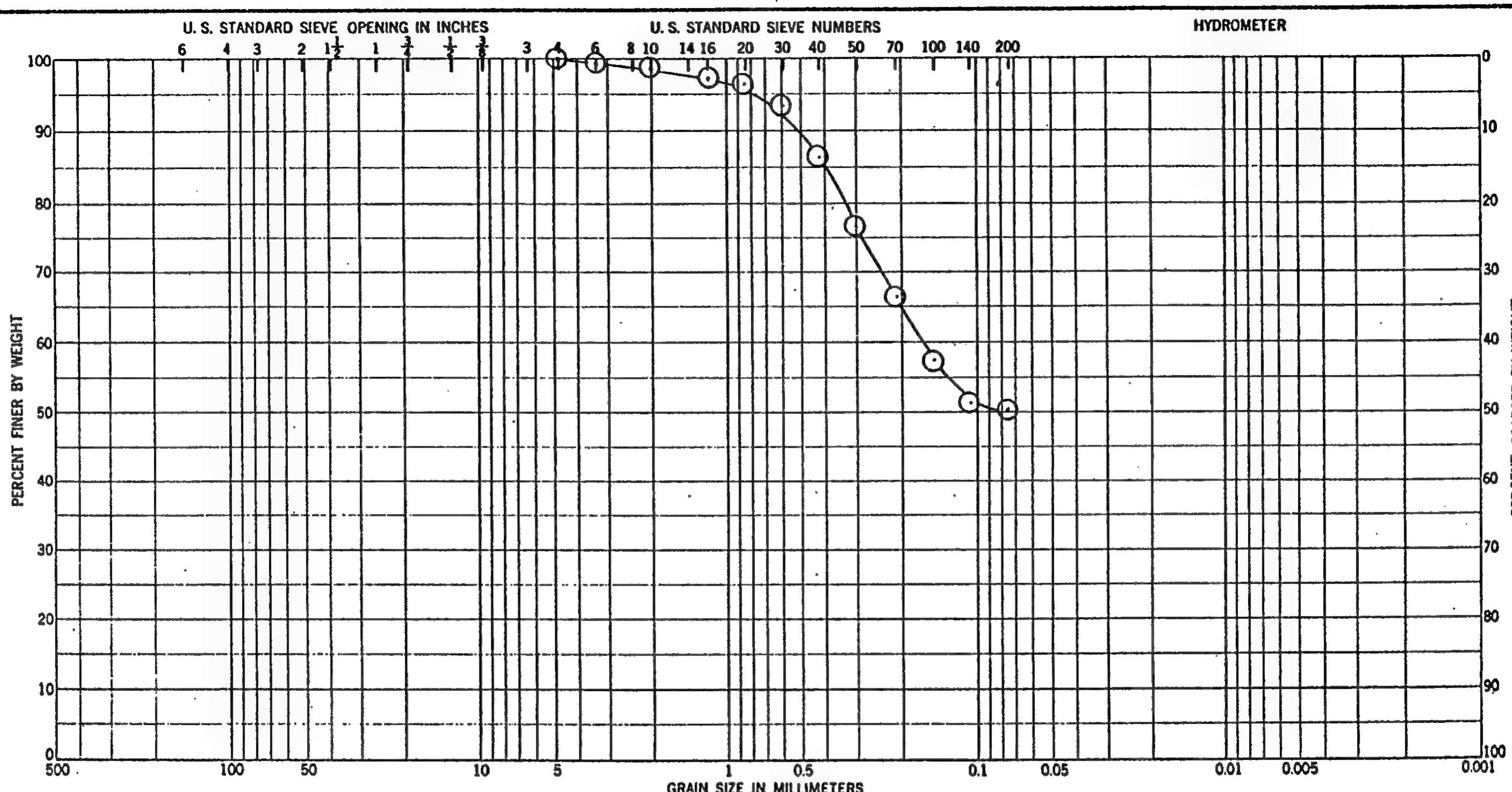
Date 10 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A80



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	29.0-30.5	SANDY CLAY (CL) BROWN				

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GRADATION CURVES

Results of Sieve Analysis

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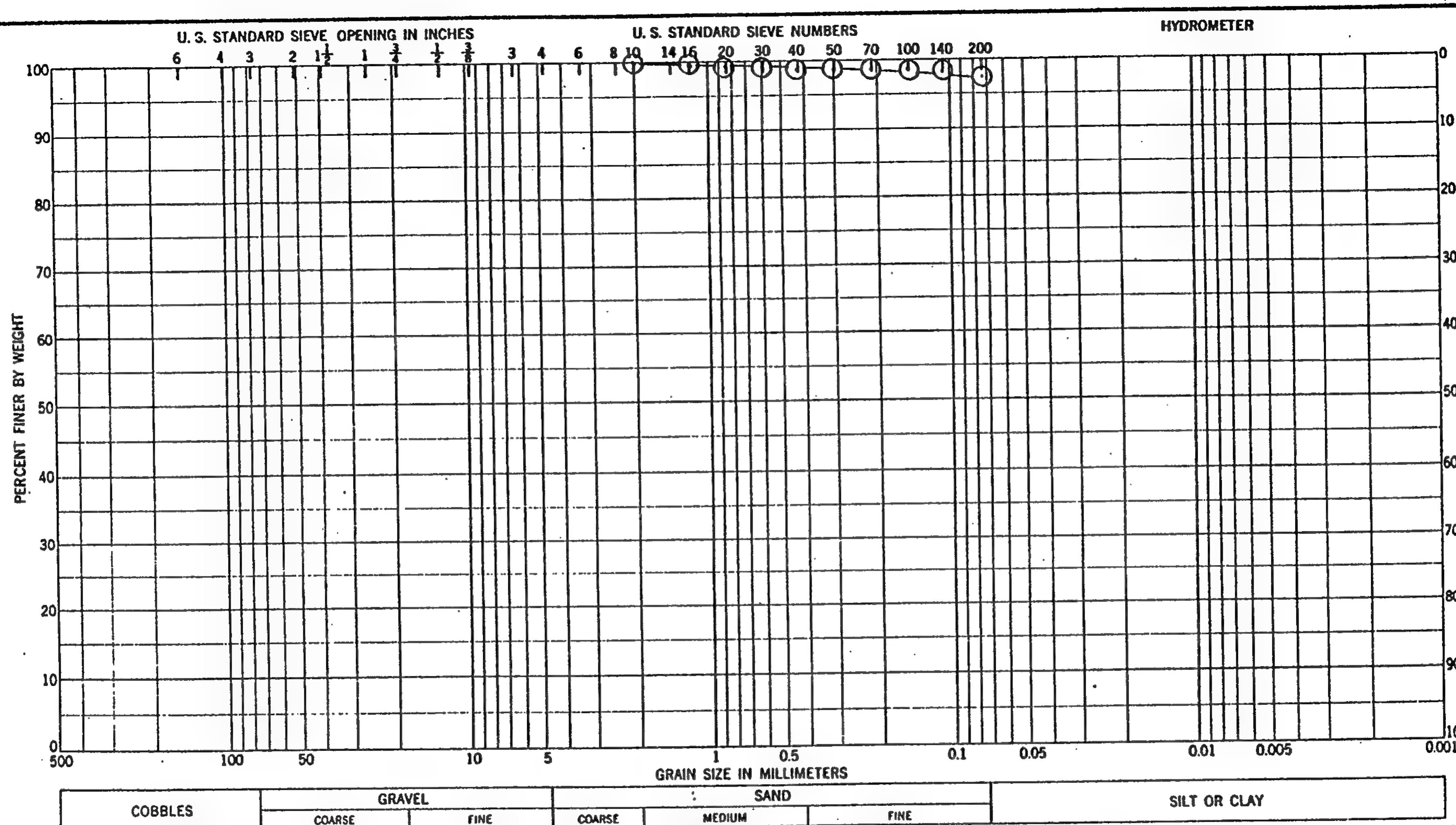


Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
11	50.0-51.5	CLAY (CH) GRAY		54	21	33

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No. 947

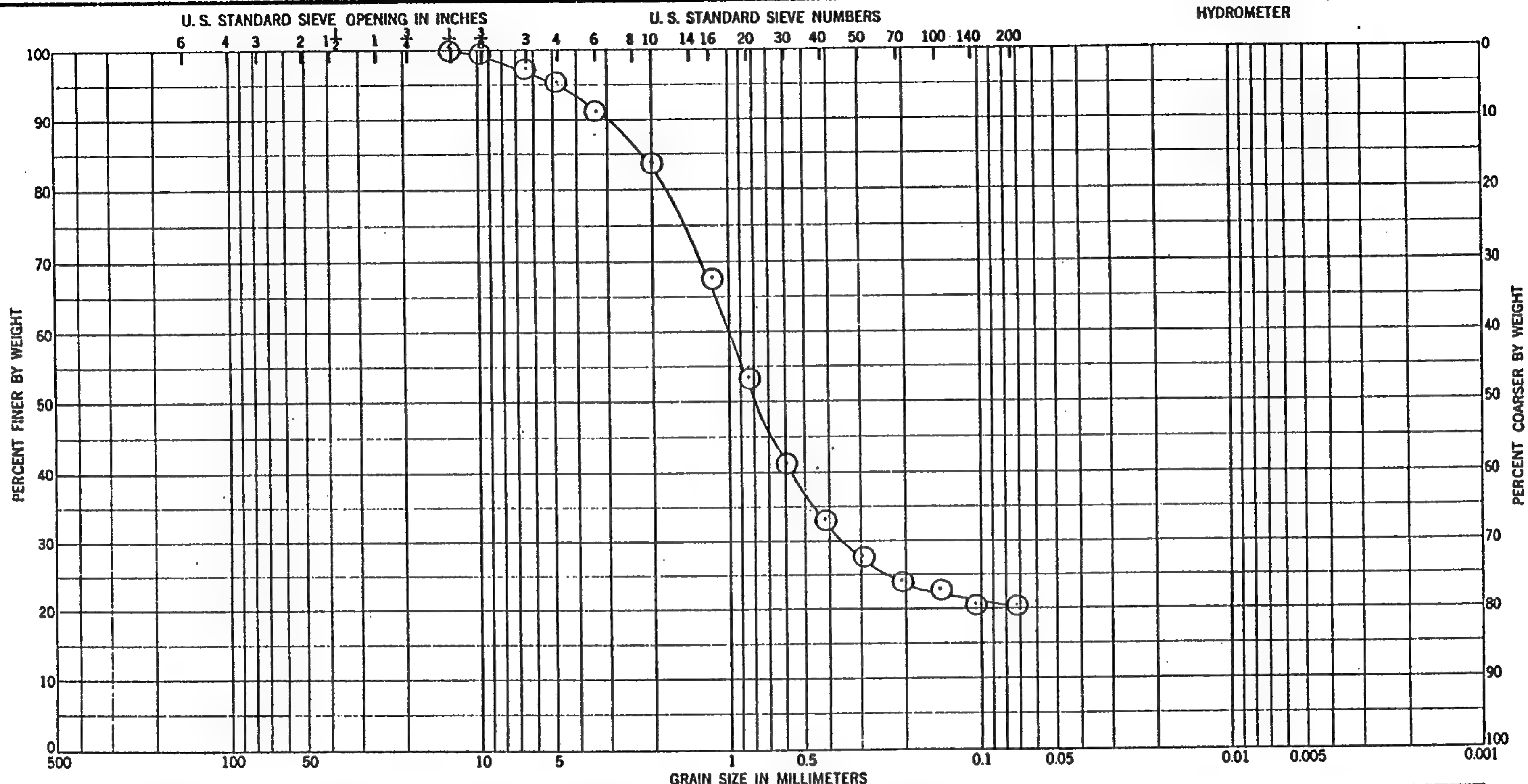
Date: 3 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A82

ENG FORM 1 MAY 63 2087



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	SILTY SAND (SM) WITH TRACE GRAVEL BROWN				

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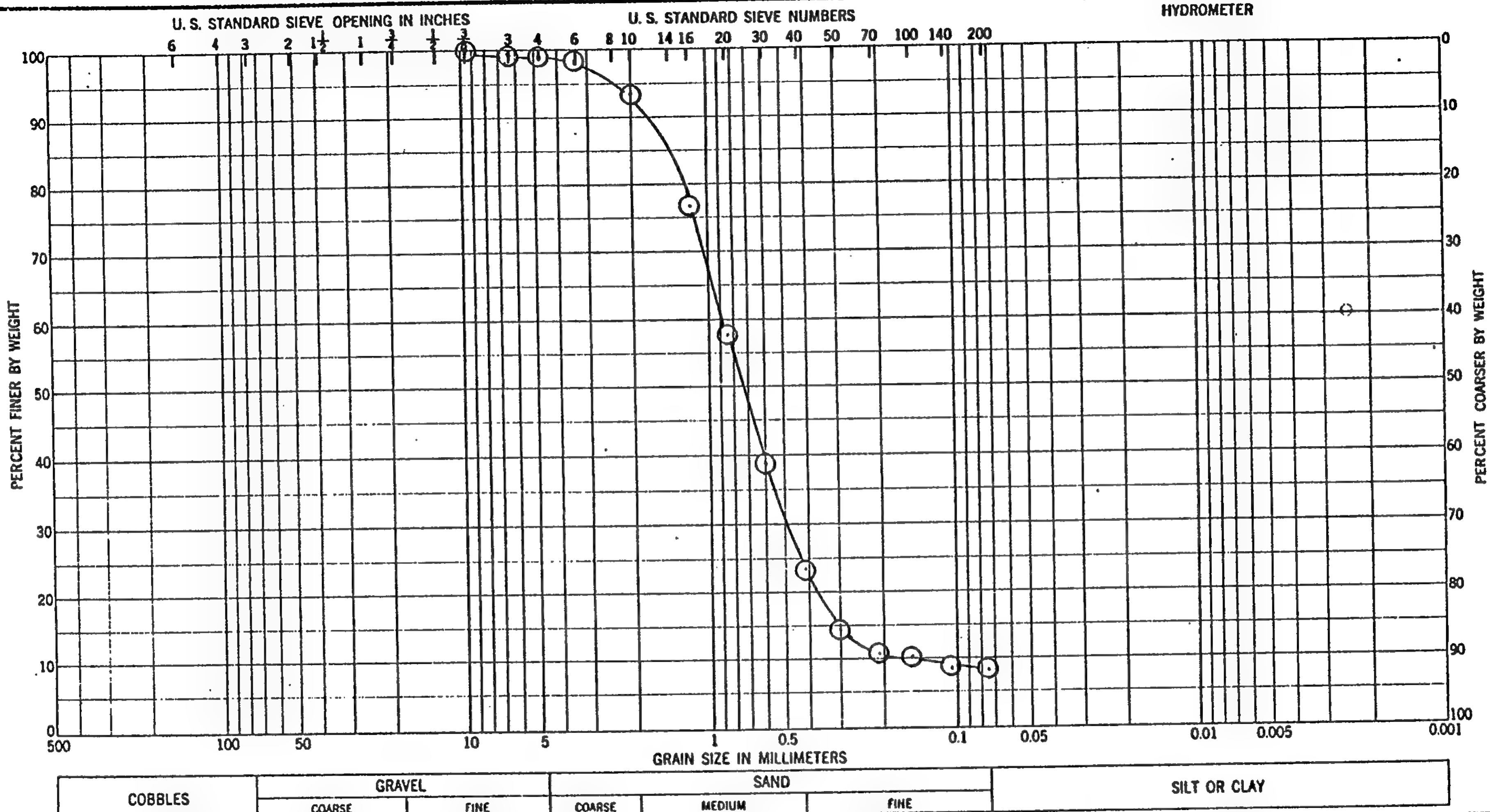
GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	SILTY SAND (SP-SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 951

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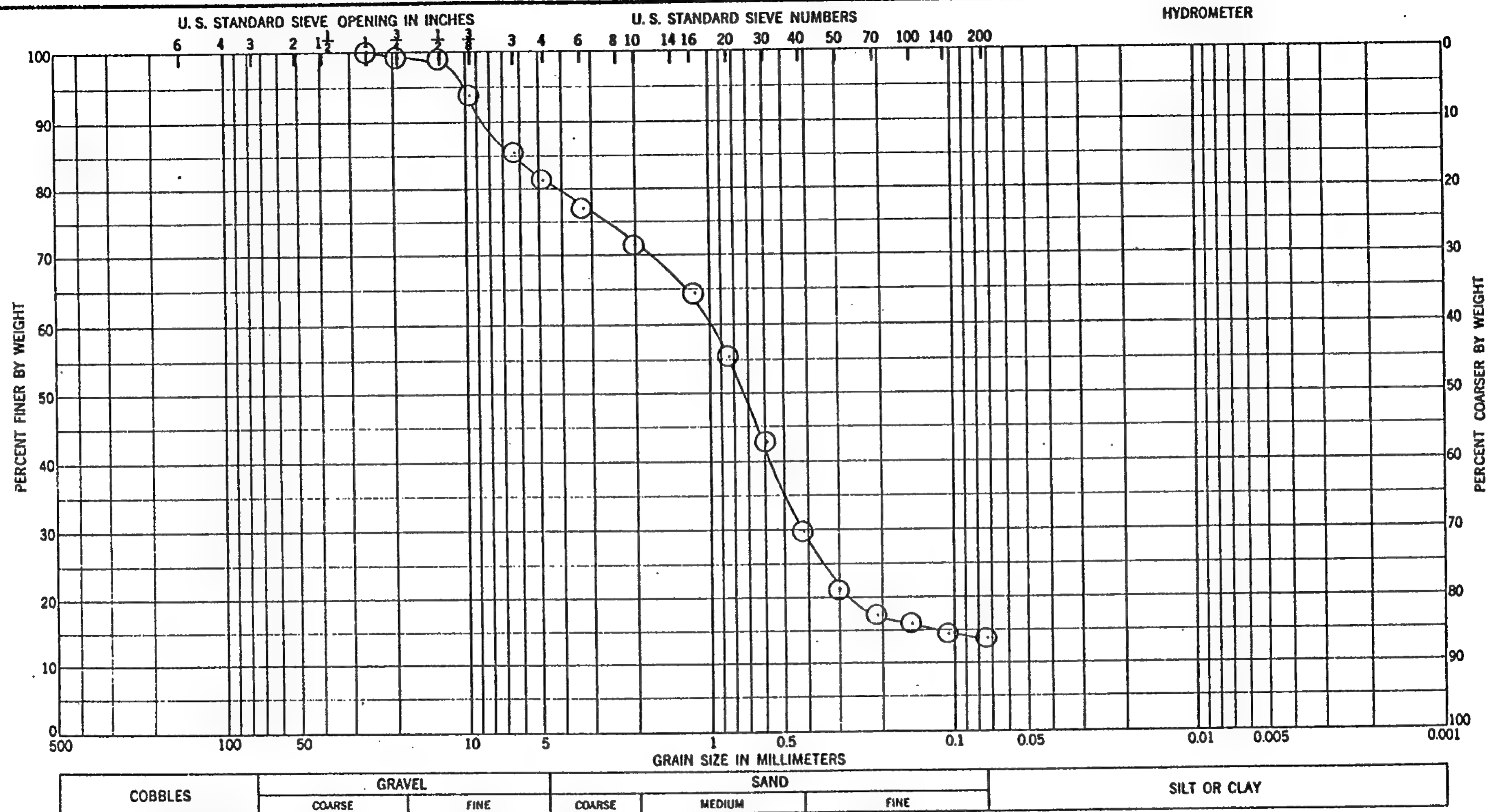
GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A84



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	SILTY SAND (SM) BROWN				

Project	ROCKY MOUNTAIN ARSENAL
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Boring No.	952
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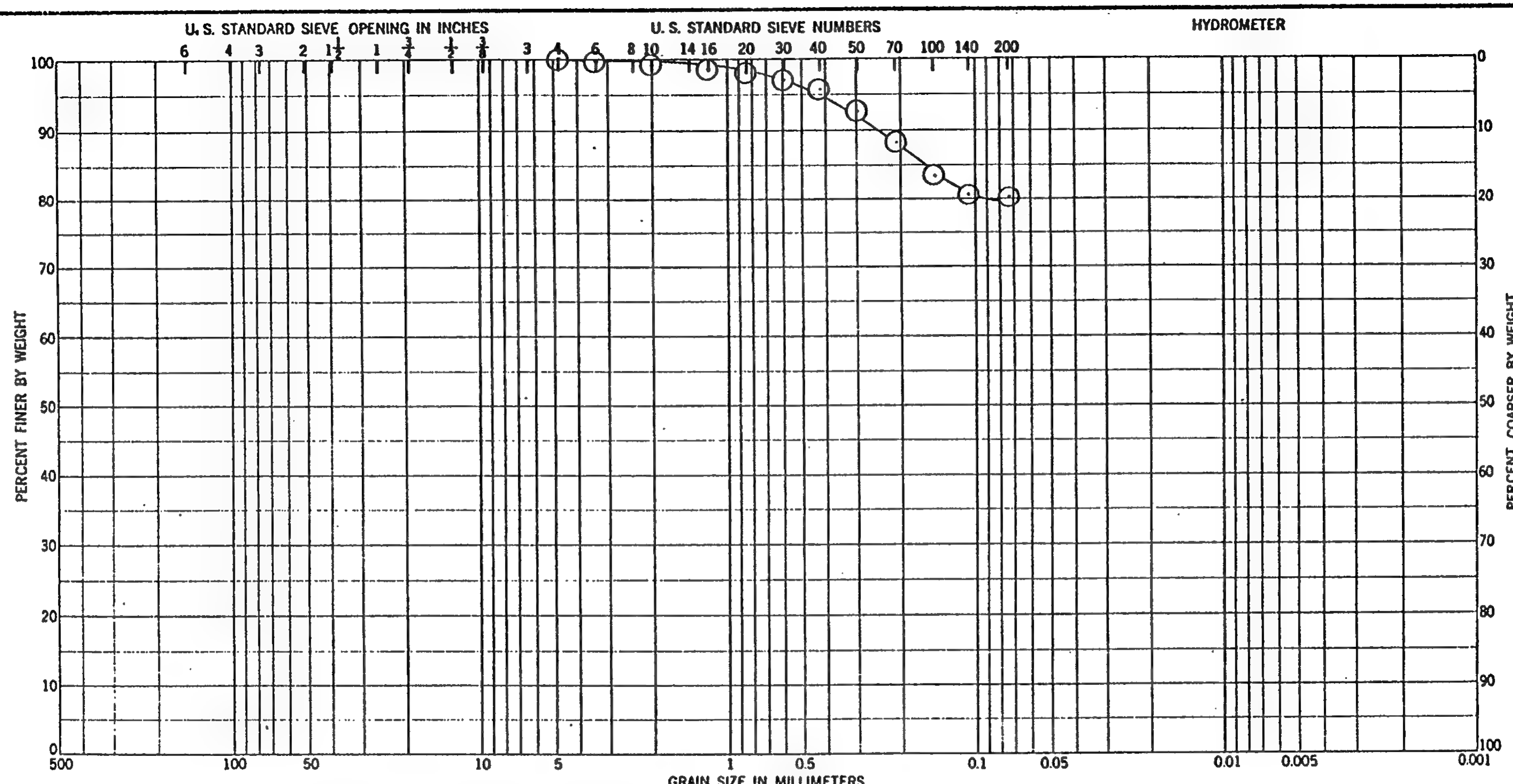
GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A85



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
1	0.0-1.5	SANDY CLAY (CL) BROWN		36	21	15

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 953

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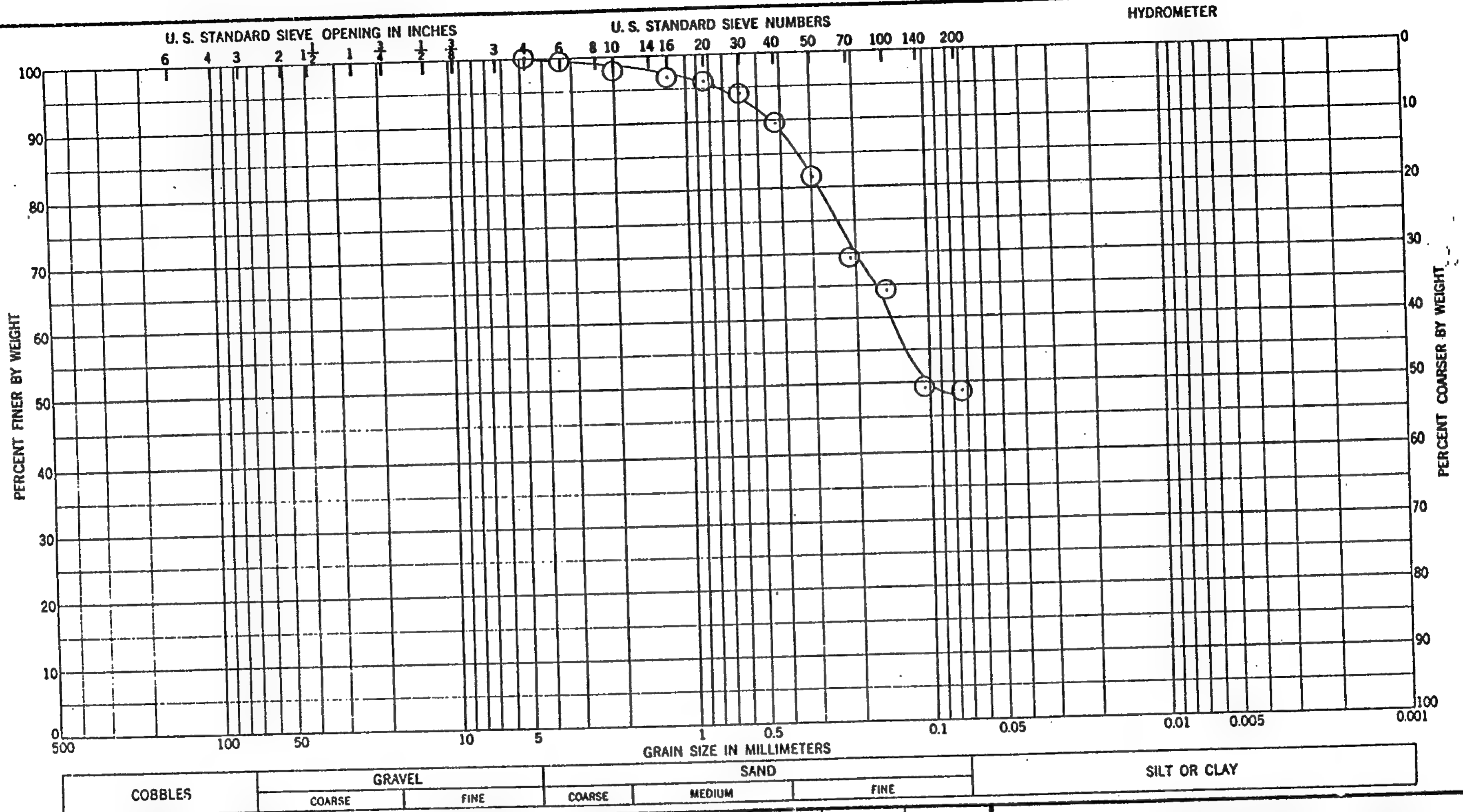
GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
2	5.0-6.5	CLAYEY SAND (SC) BROWN		39	18	21

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	953
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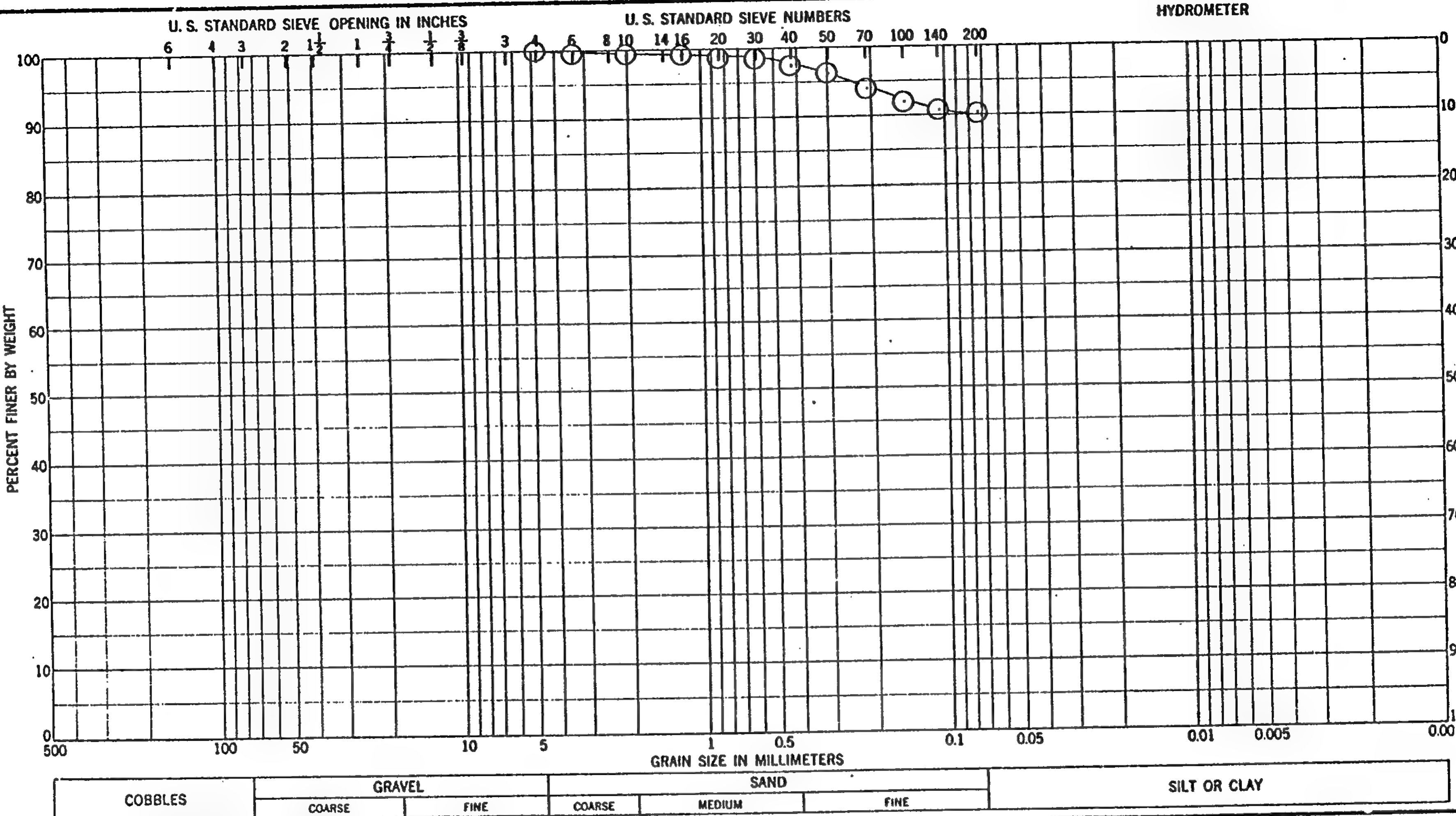
GRADATION CURVES

Results of Sieve Analysis

Plate A87

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
3	10.0-11.5	CLAY (CH) WITH SAND BROWN		65	21	44

Project ROCKY MOUNTAIN ARSENAL

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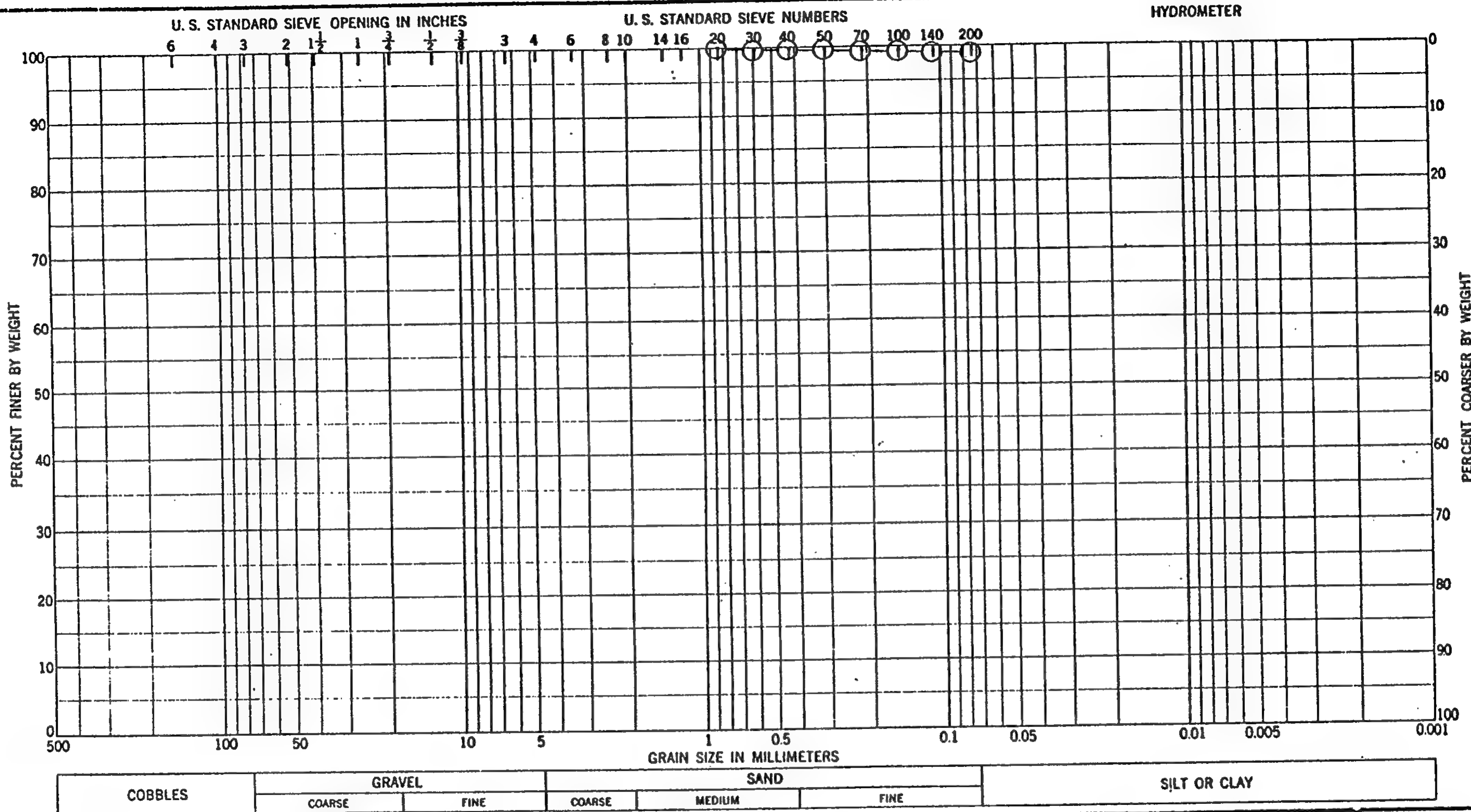
GRADATION CURVES

Results of Sieve Analysis

Plate A88

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	CLAY (CH) BROWN		66	32	34

Project	ROCKY MOUNTAIN ARSENAL
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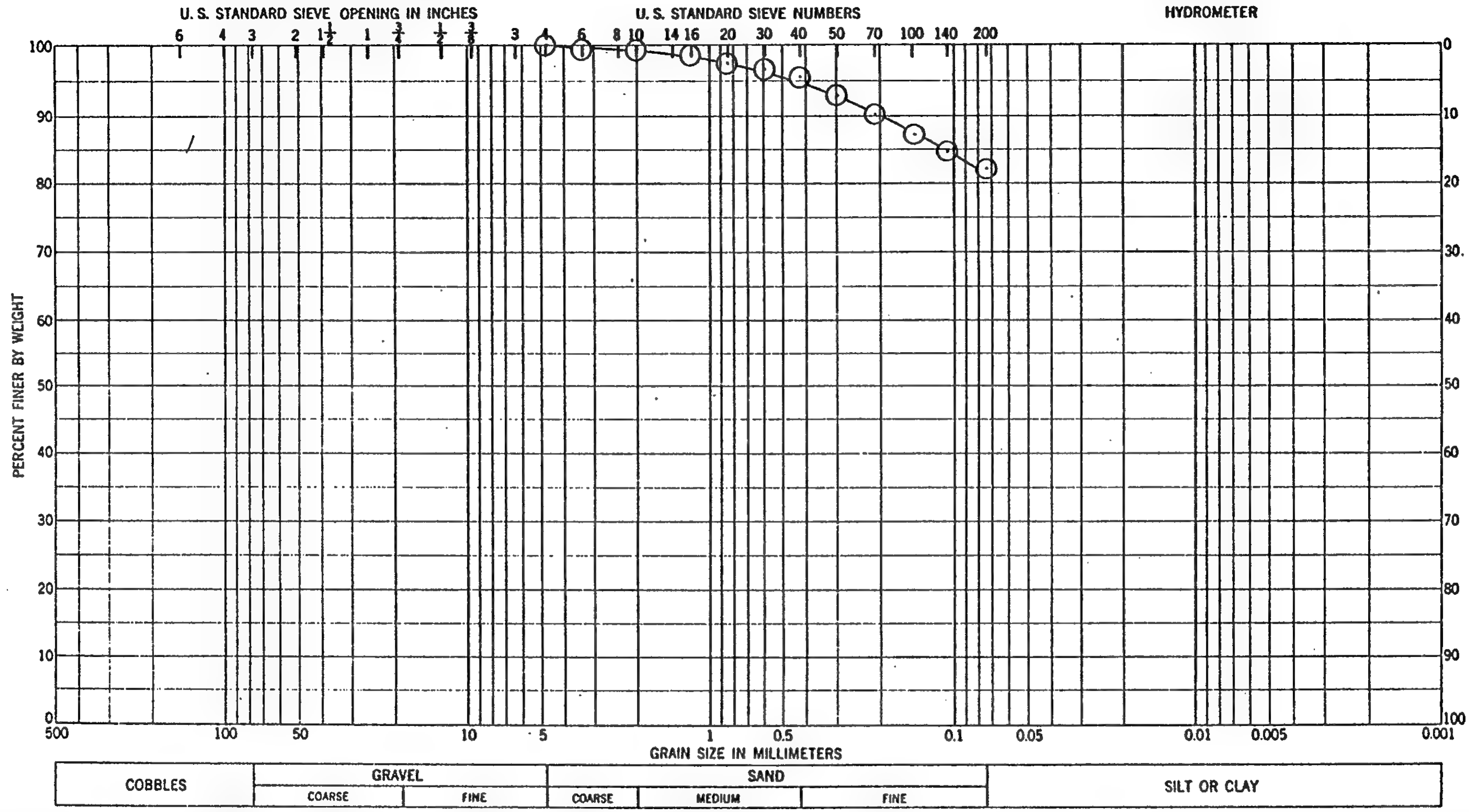
GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A89



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
1	0.0-1.5	SANDY CLAY (CL) BROWN		41	13	28

Project	ROCKY MOUNTAIN ARSENAL
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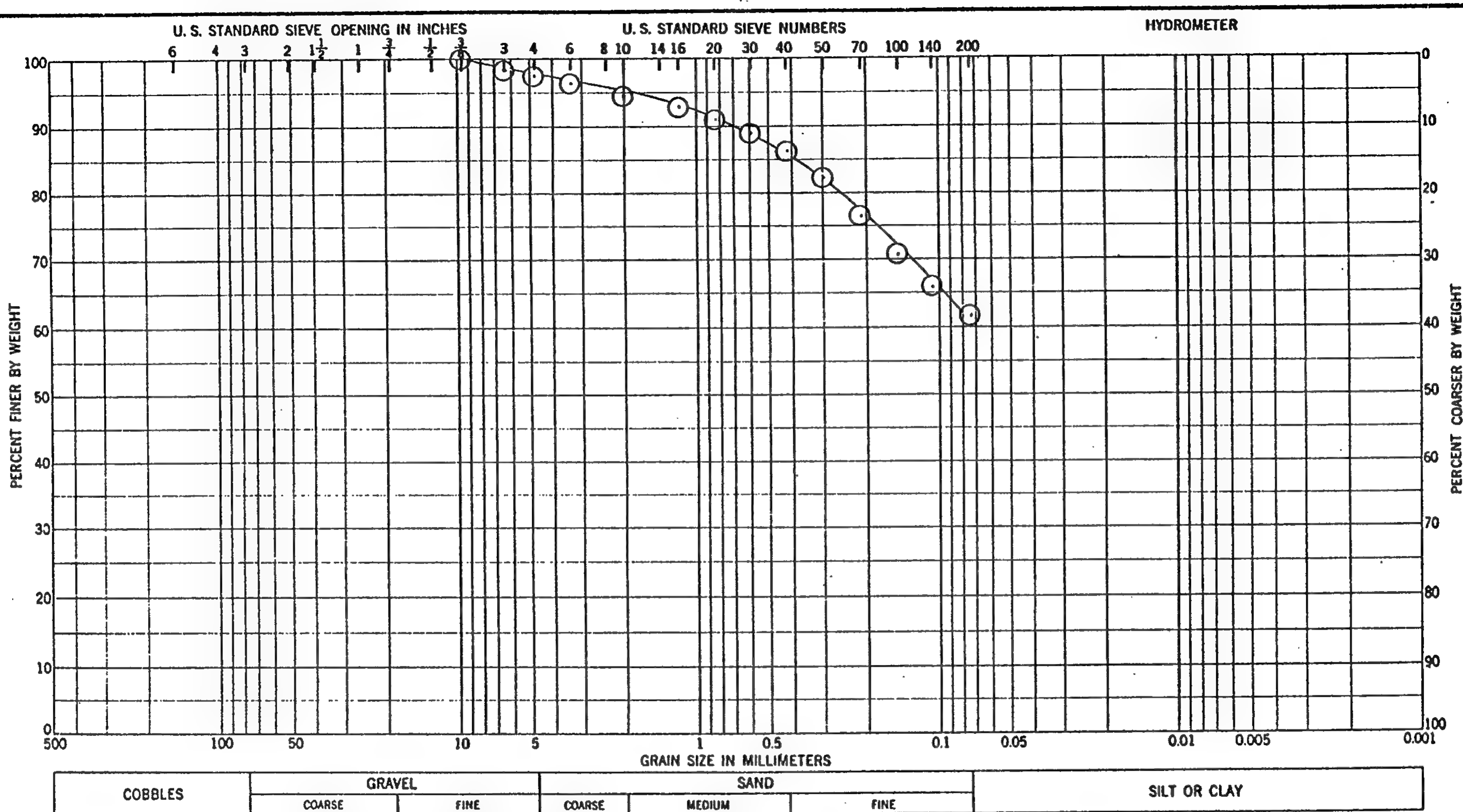
GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A90.



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
2	5.0-6.5	SANDY CLAY (CL) BROWN		37	17	20

GRADATION CURVES

Project	ROCKY MOUNTAIN ARSENAL
Area	
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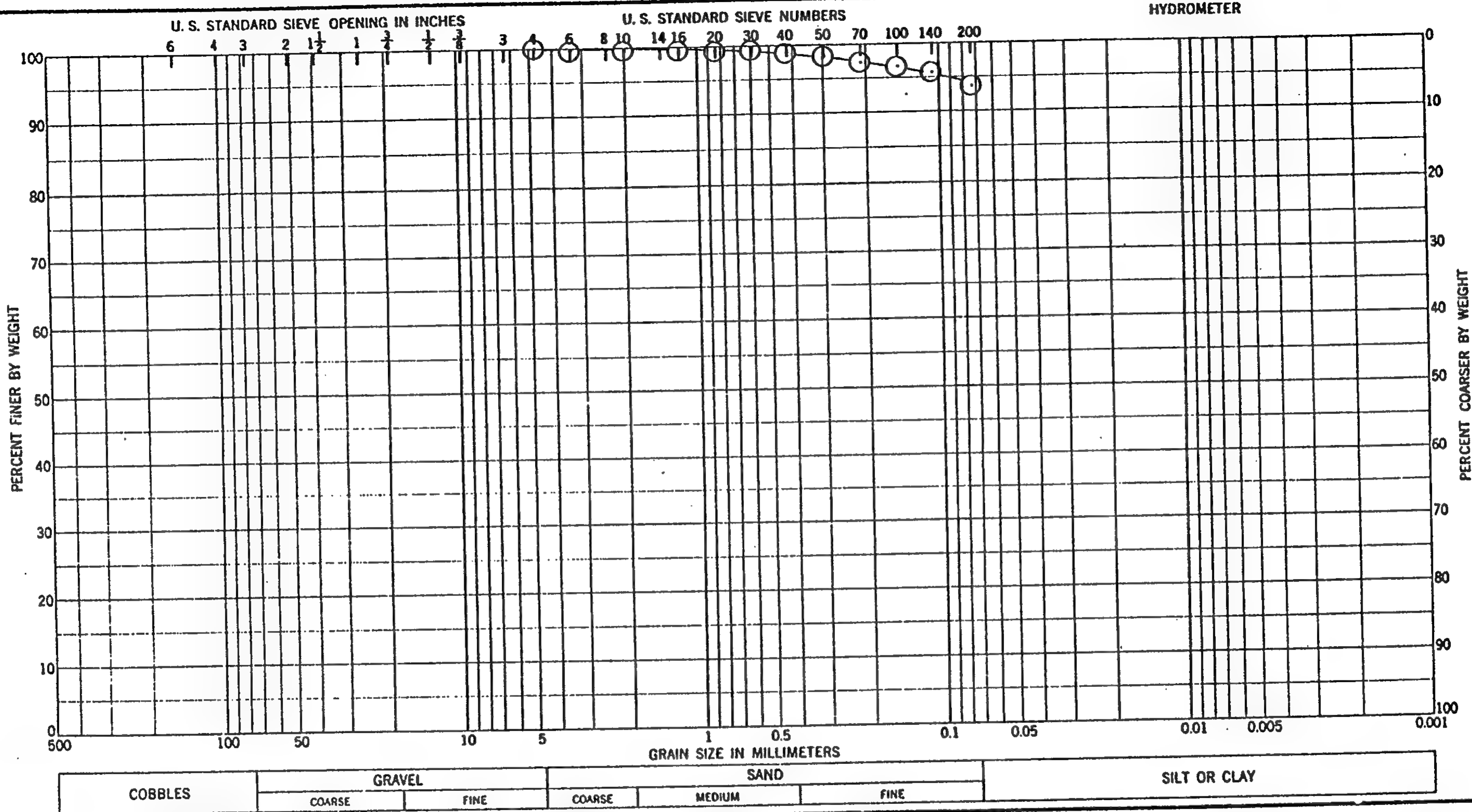
Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A91



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
3	10.0-11.5	CLAY (CH) WITH SAND BROWN		63	28	35

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GRADATION CURVES

Results of Sieve Analysis

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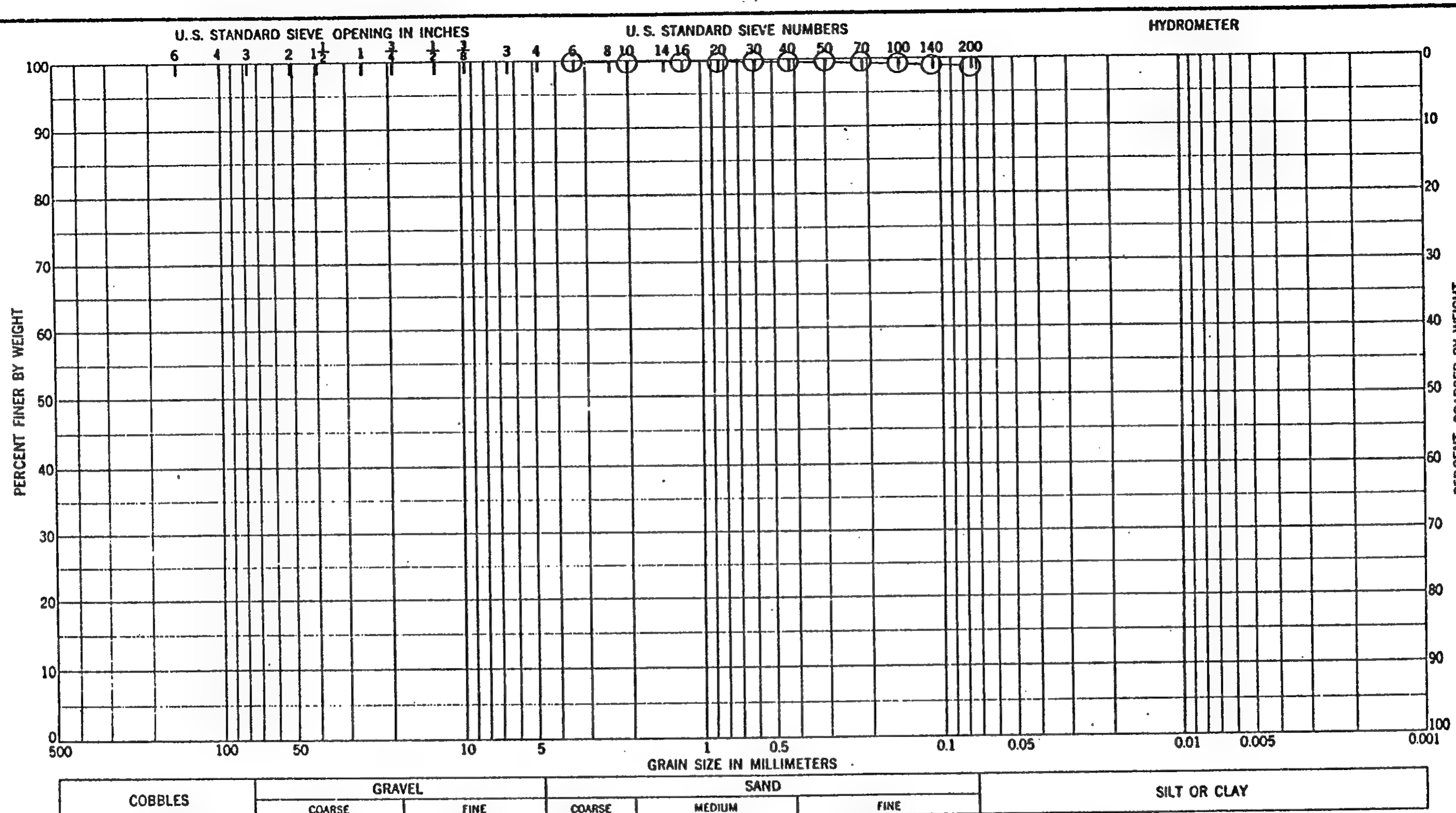

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	SILT (MH) BROWN		72	44	28

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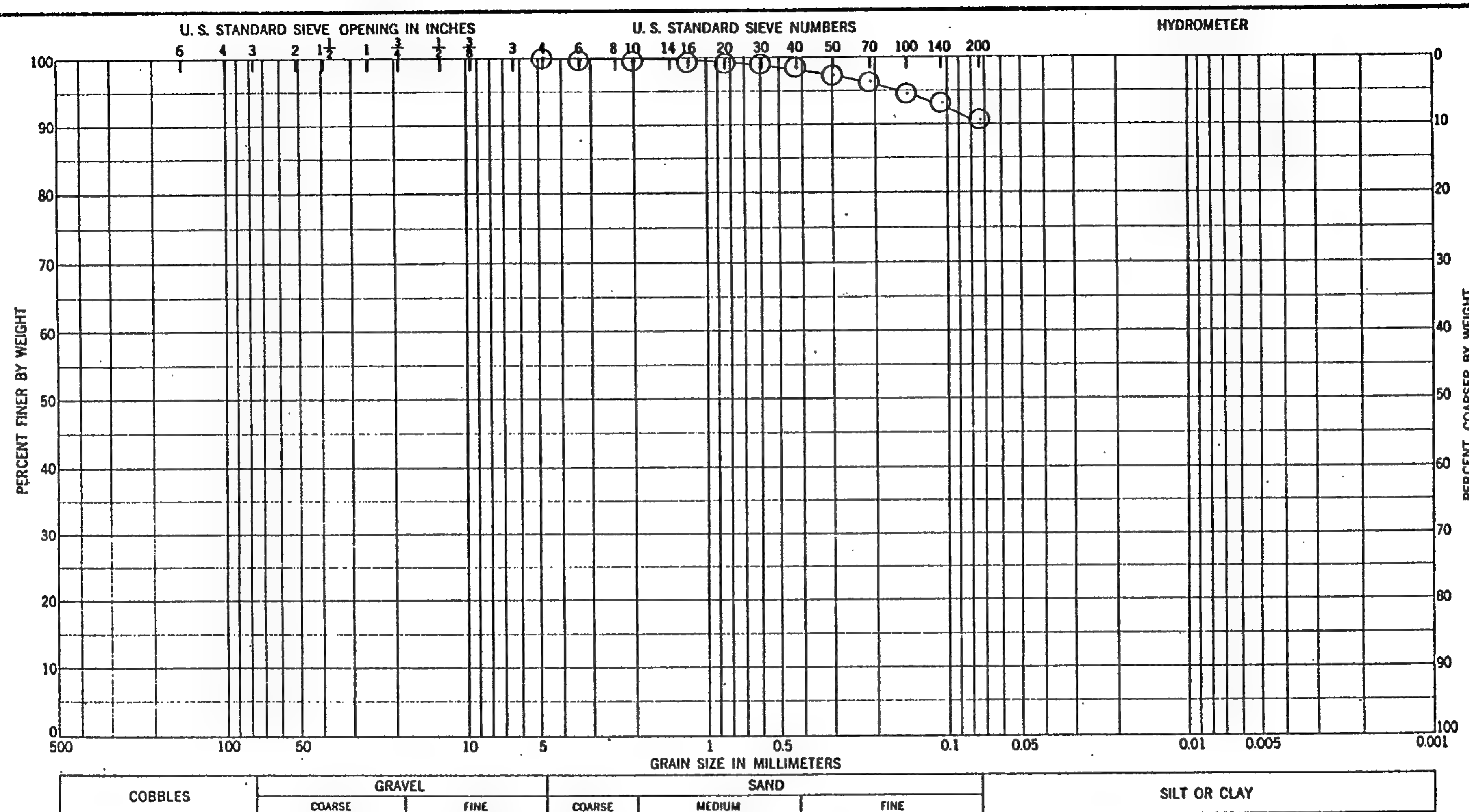
GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A93



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
1	0.0-1.5	CLAY (CL) WITH SAND BROWN		40	15	25

GRADATION CURVES

Project	ROCKY MOUNTAIN ARSENAL
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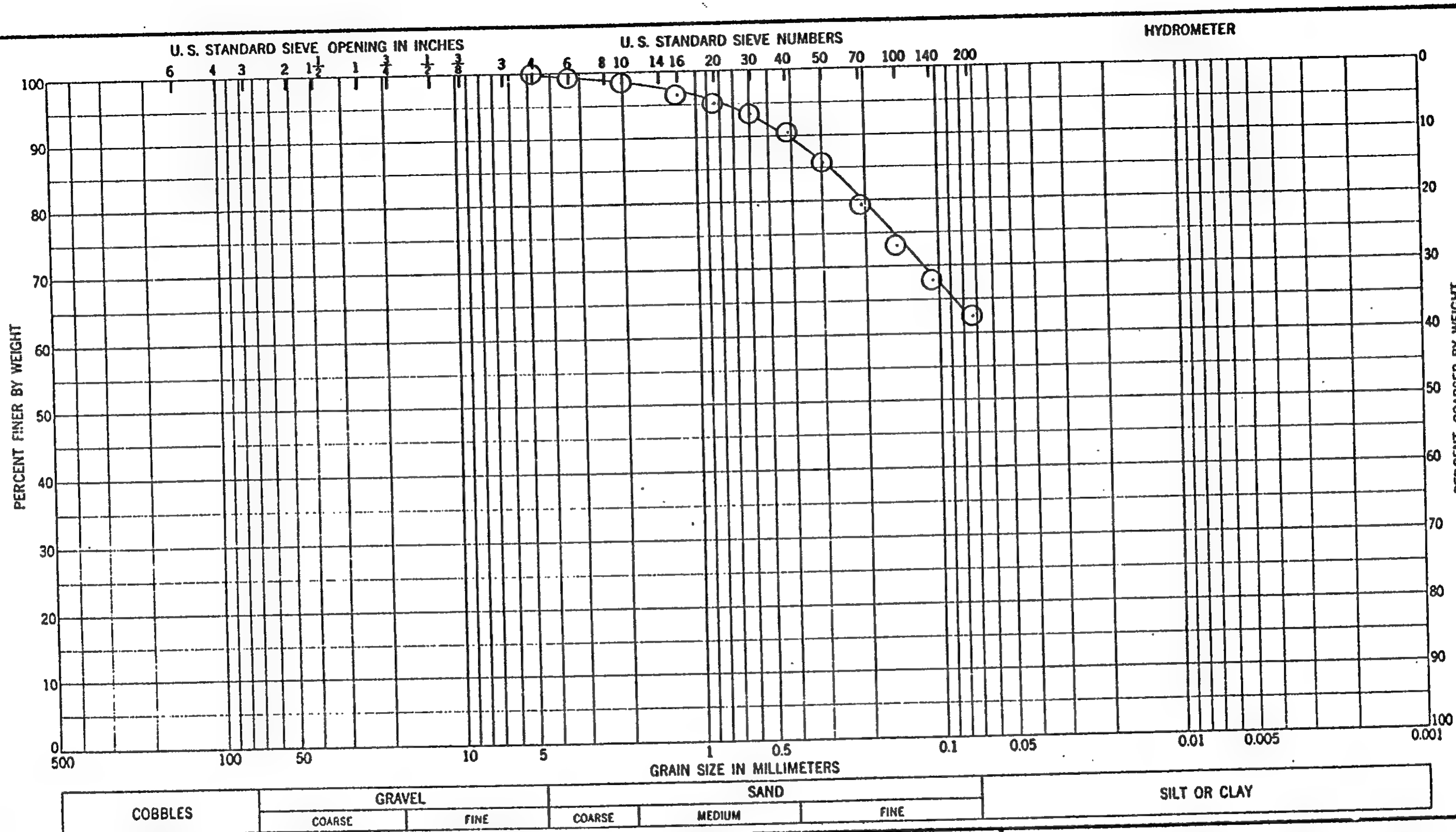
Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
2	5.0-6.5	SANDY CLAY (CL) BROWN				

Project ROCKY MOUNTAIN ARSENAL

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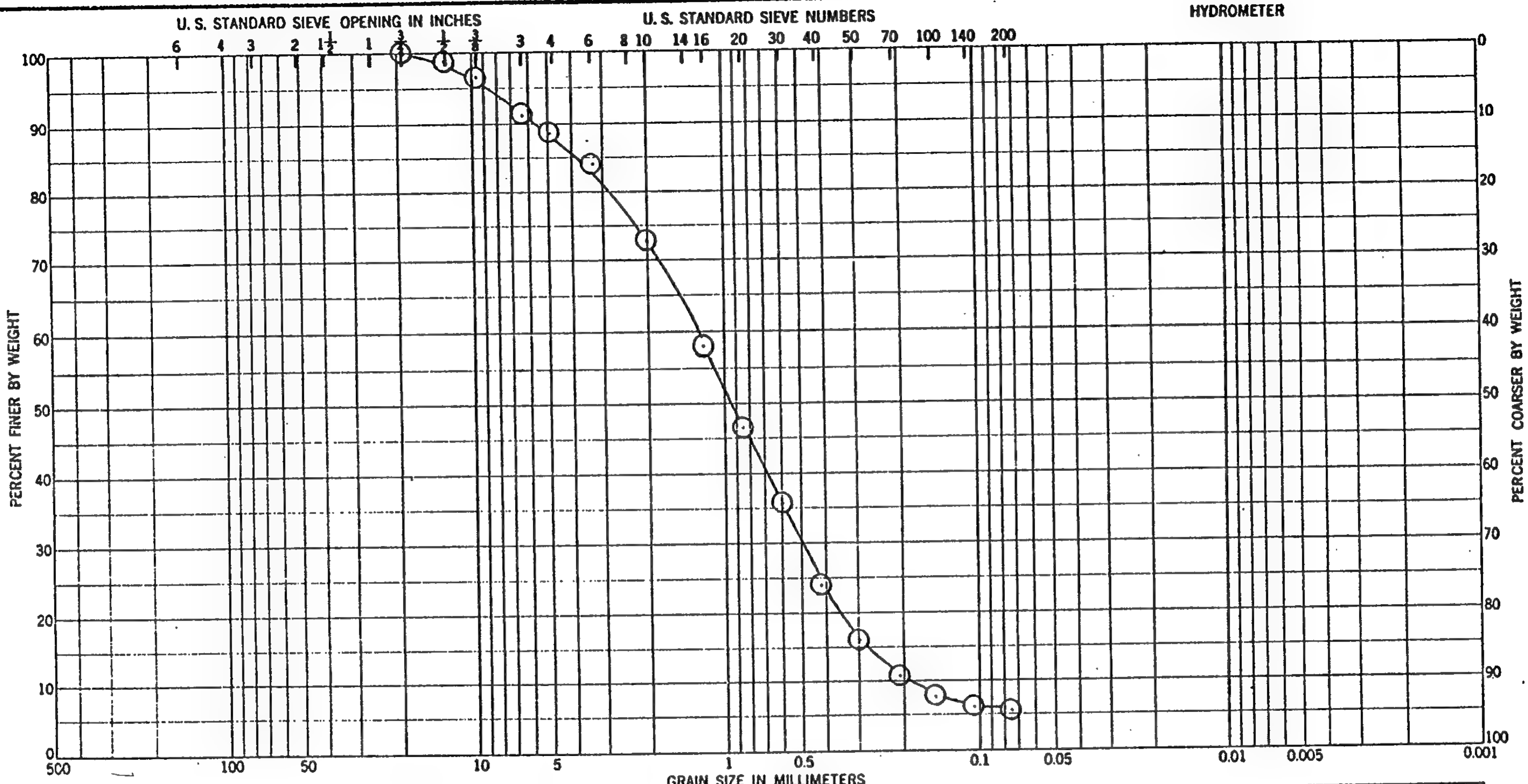
GRADATION CURVES

Results of Sieve Analysis

Plate A95

ENG FORM 1 MAY 63 2087



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
3	10.0-11.5	SILTY SAND (SW-SM) WITH GRAVEL TAN				

Project ROCKY MOUNTAIN ARSENAL

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GRADATION CURVES

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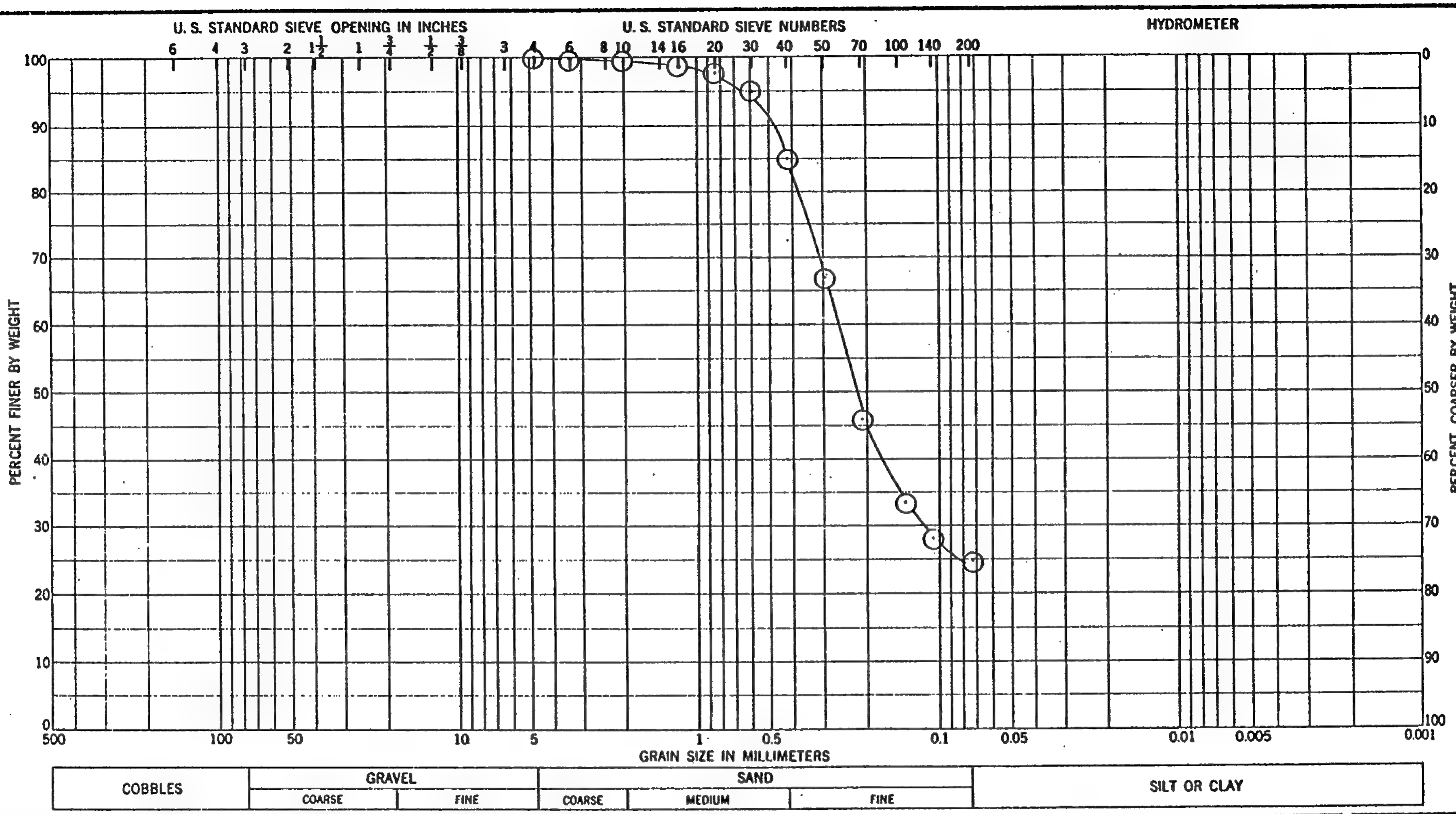
Results of Sieve Analysis

Plate A96



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	CLAYEY SAND (SC) TAN		34	13	21

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

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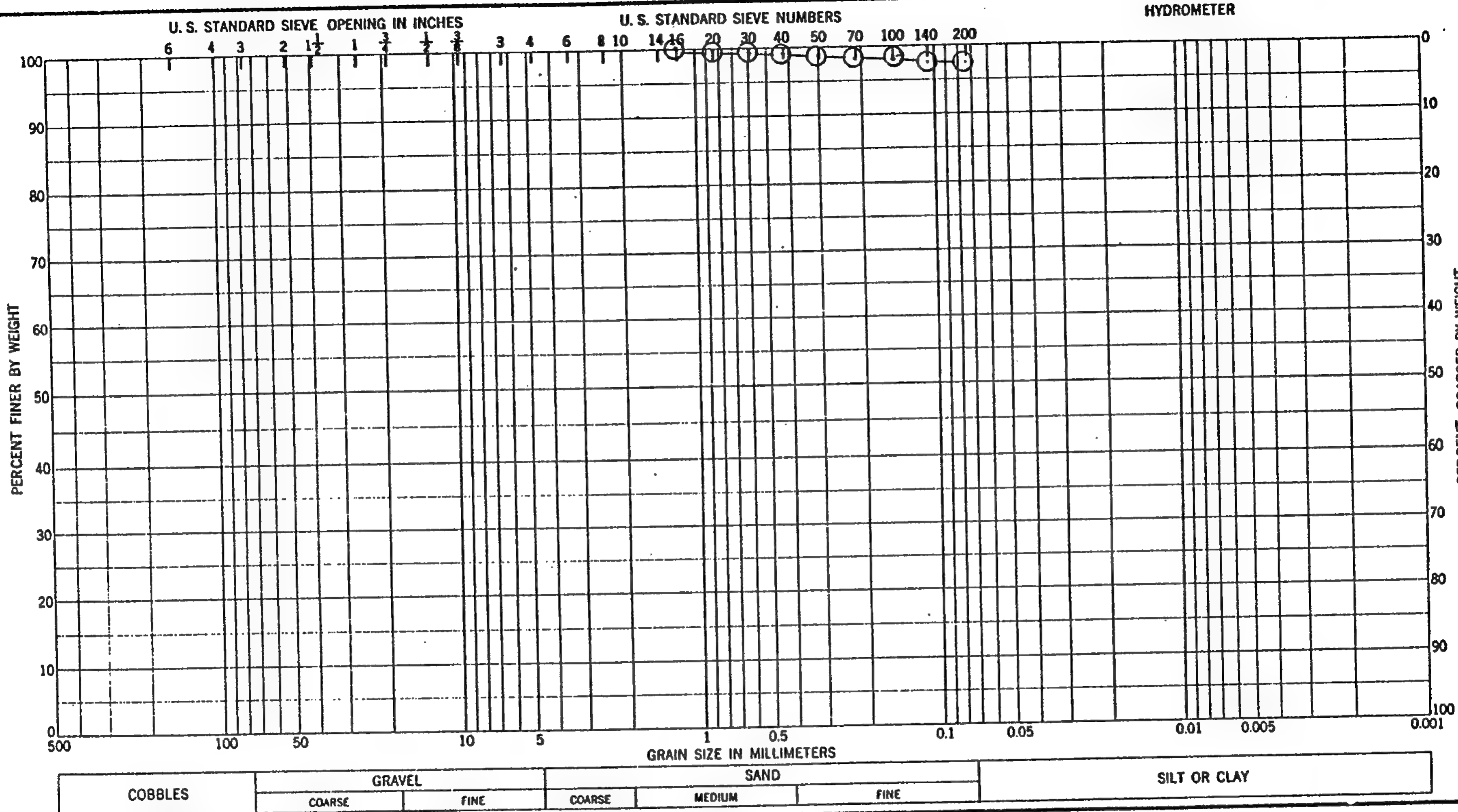
ENG FORM 1 MAY 63 2087

Plate A97



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	20.0-21.5	CLAY (CH) BROWN		62	18	44

Project ROCKY MOUNTAIN ARSENAL

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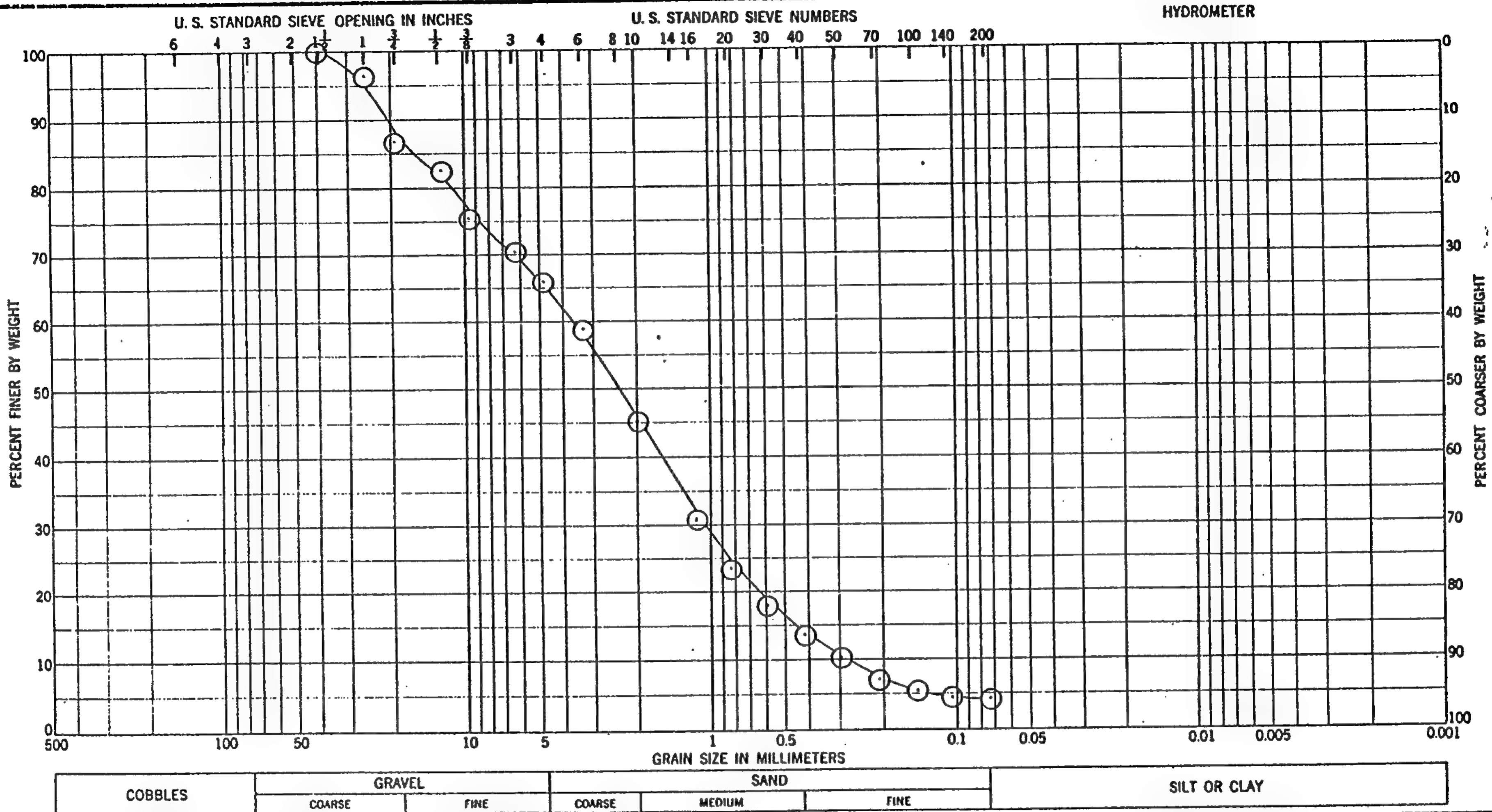
GRADATION CURVES

Results of Sieve Analysis

Plate A98

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	25.0-26.5	GRAVELLY SAND (SW) BROWN				

Project ROCKY MOUNTAIN ARSENAL

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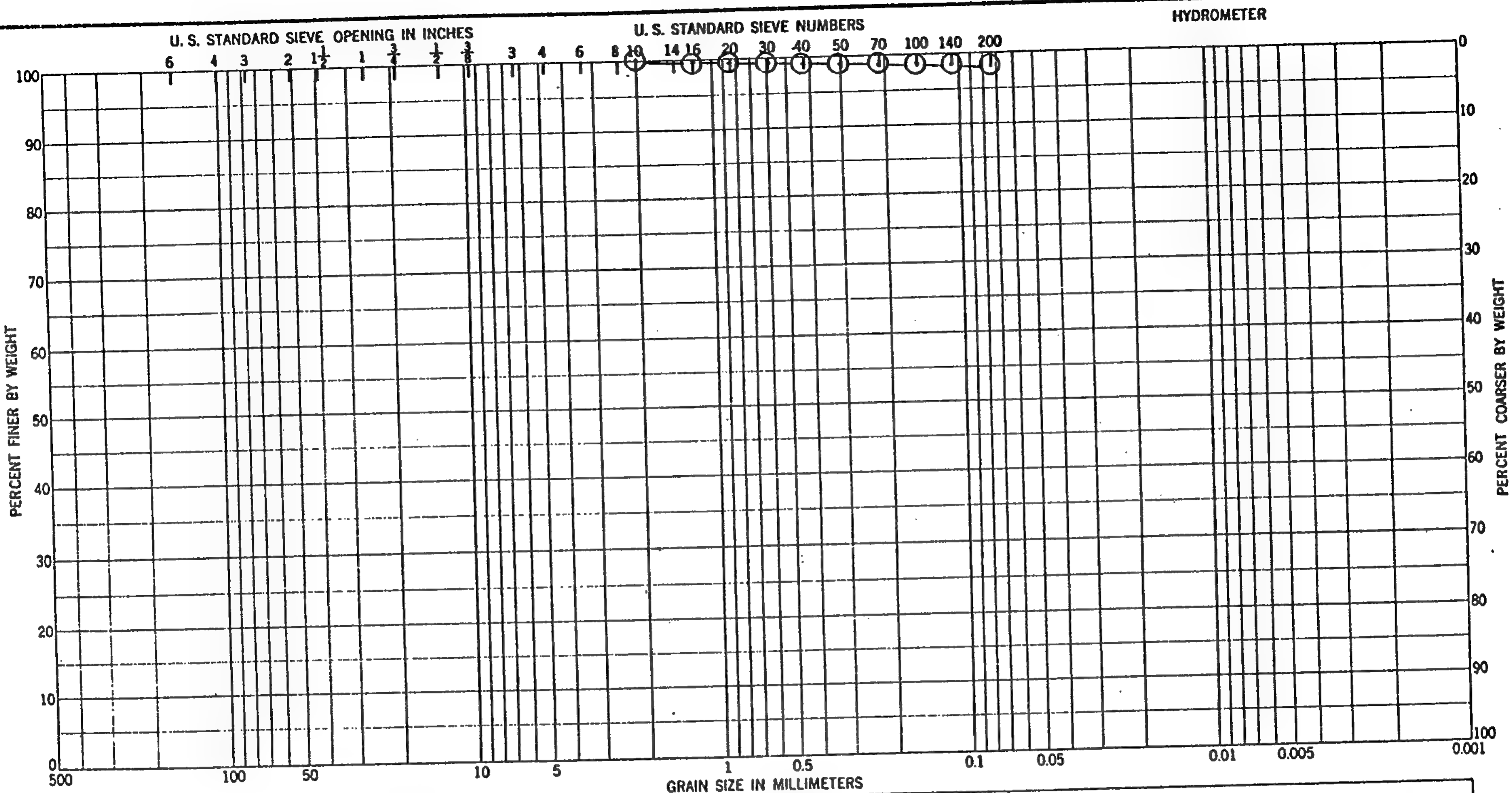
GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A99



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	30.0-31.5	CLAY (CH) GRAY		74	34	40

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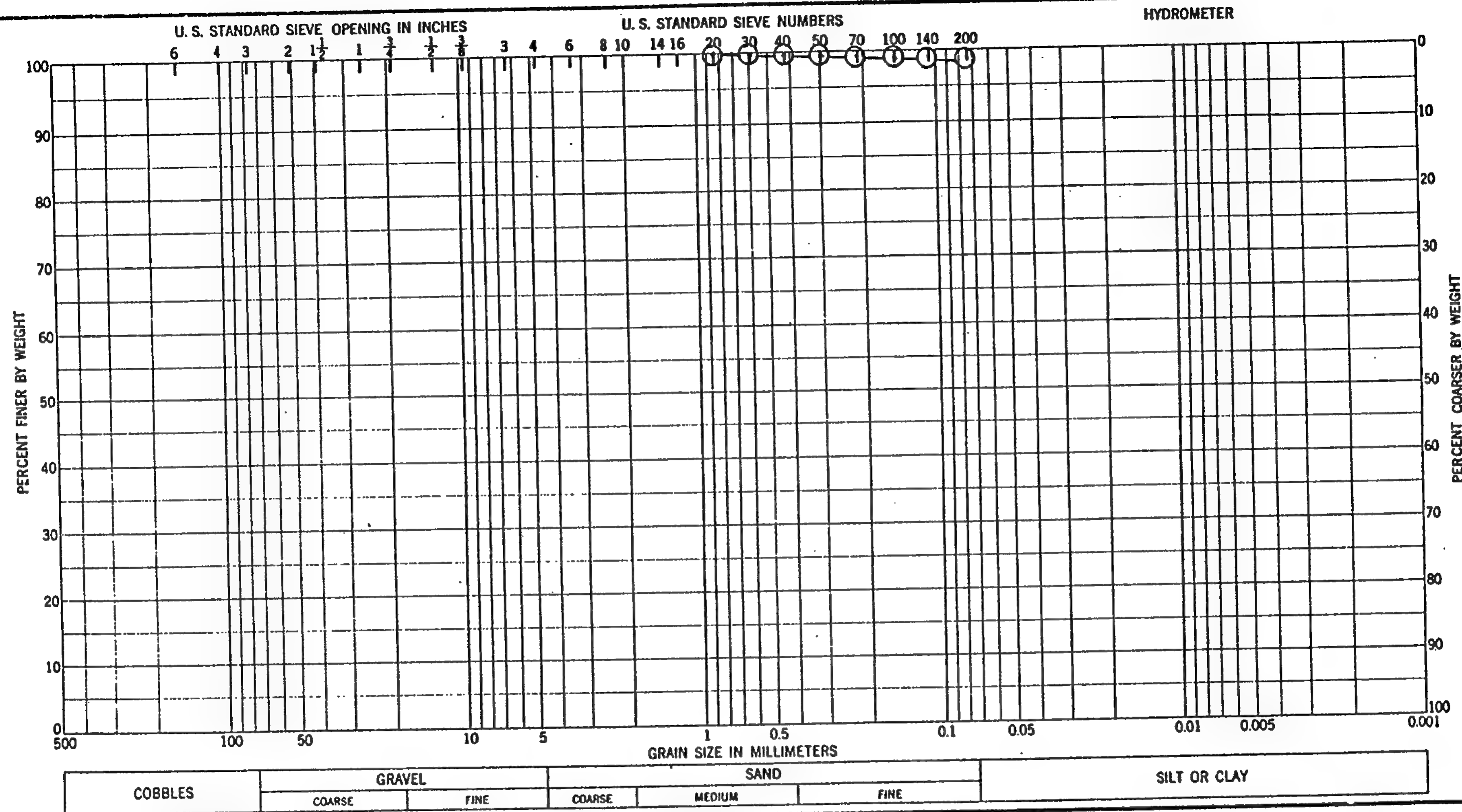
GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A100



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	35.0-36.5	CLAY (CH) GRAY		58	25	33

Project ROCKY MOUNTAIN ARSENAL

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GRADATION CURVES

Results of Sieve Analysis

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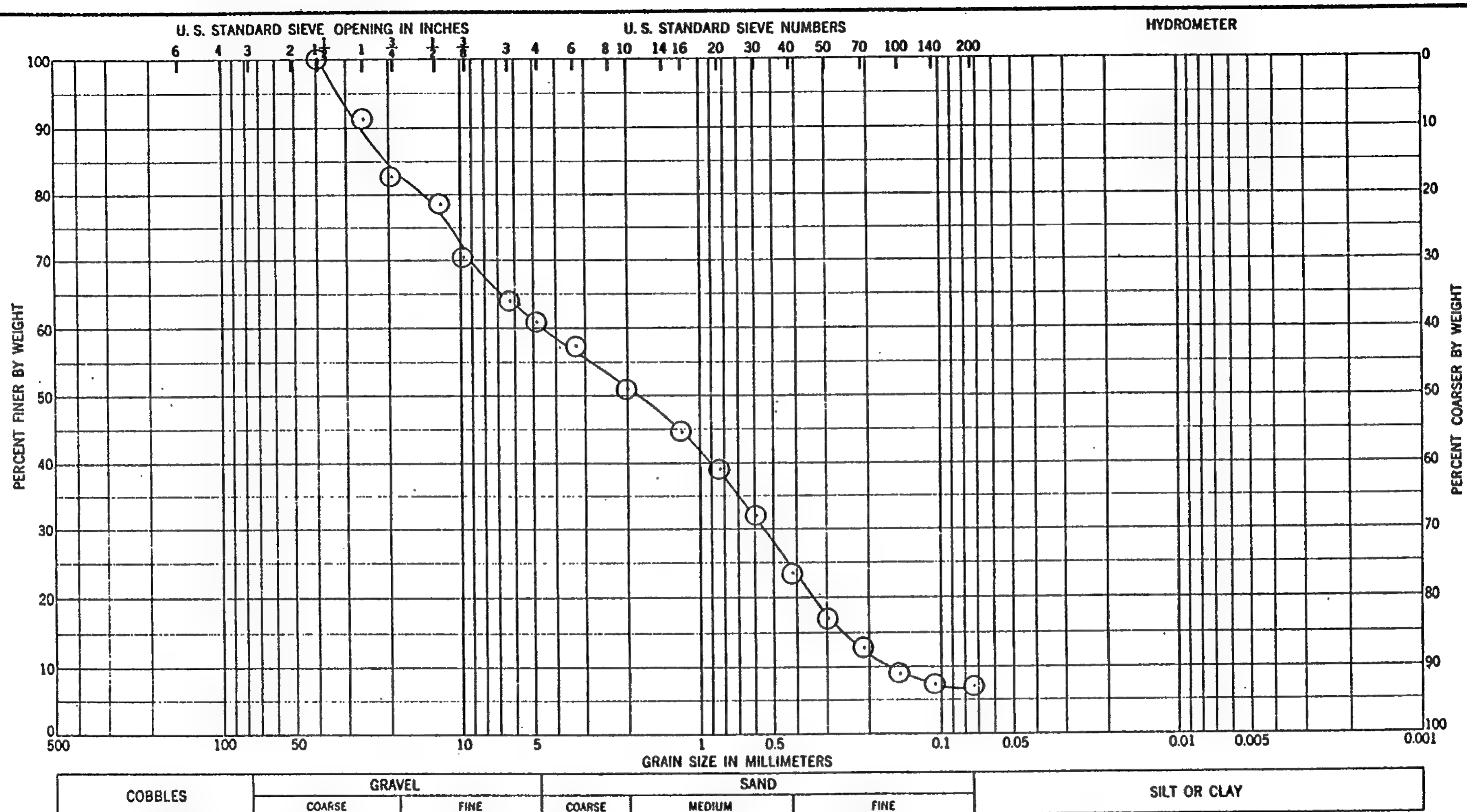
Plate A101



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7	30.0-31.5	GRAVELLY SILTY SAND (SP-SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

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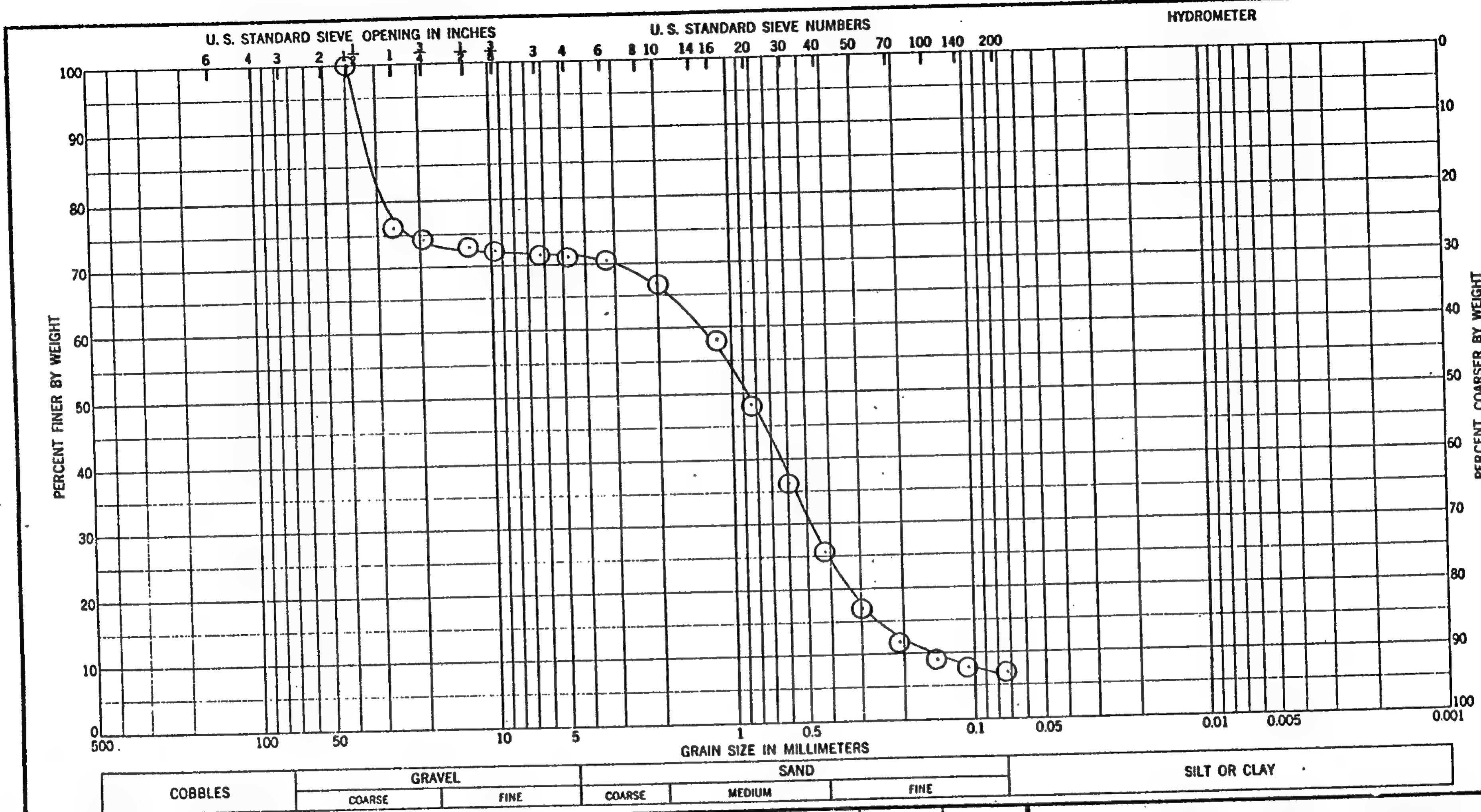
GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	19.0-20.5	GRAVELLY SILTY SAND (SW-SM) BROWN				

Project ROCKY MOUNTAIN ARSENAL

Area

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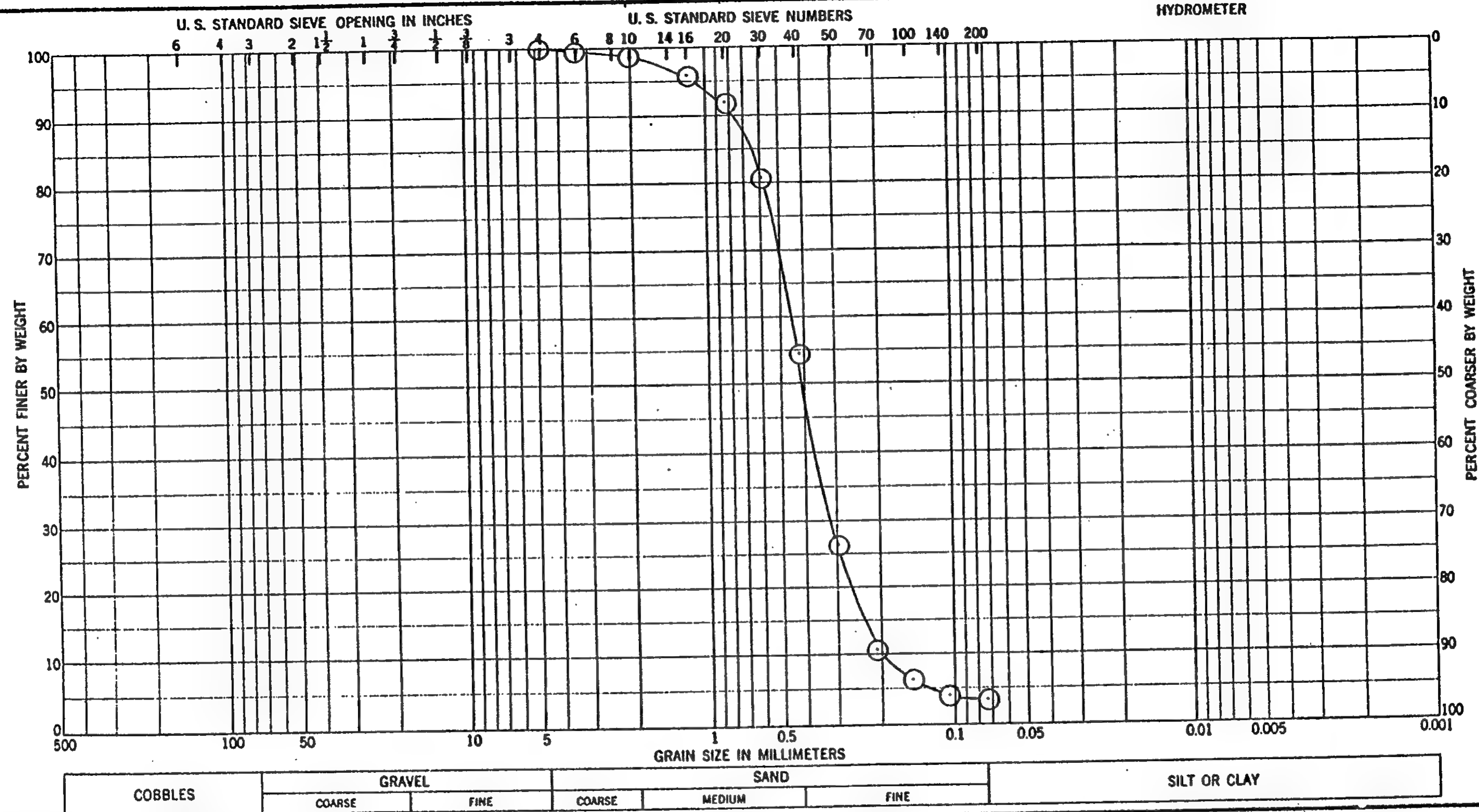
GRADATION CURVES

Results of Sieve Analysis

Plate A103

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	SAND (SP) BROWN				

Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	958
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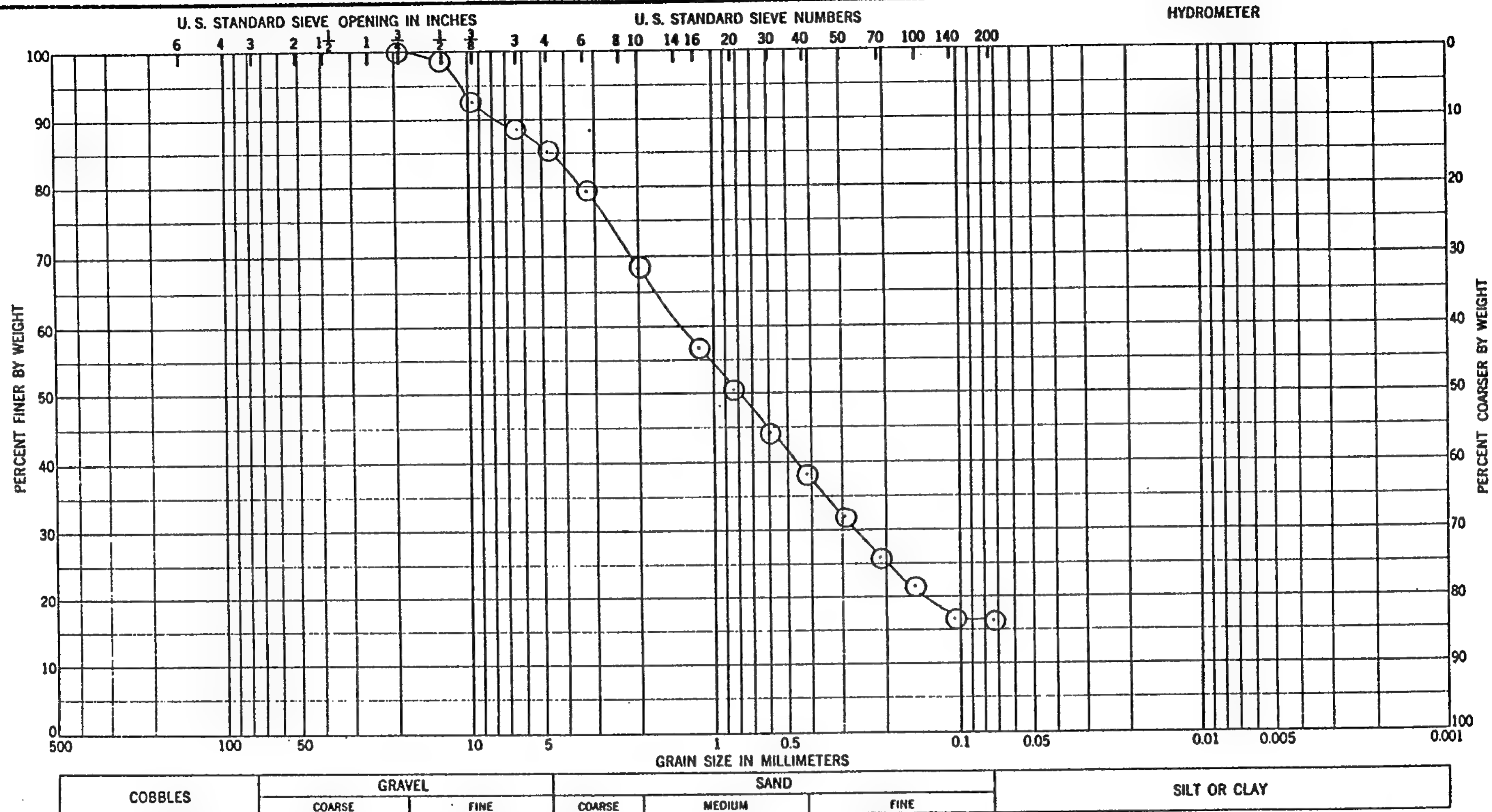
GRADATION CURVES

Results of Sieve Analysis

Plate A104

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	35.0-36.5	GRAVELLY SILTY SAND (SM) TAN				

GRADATION CURVES

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 959

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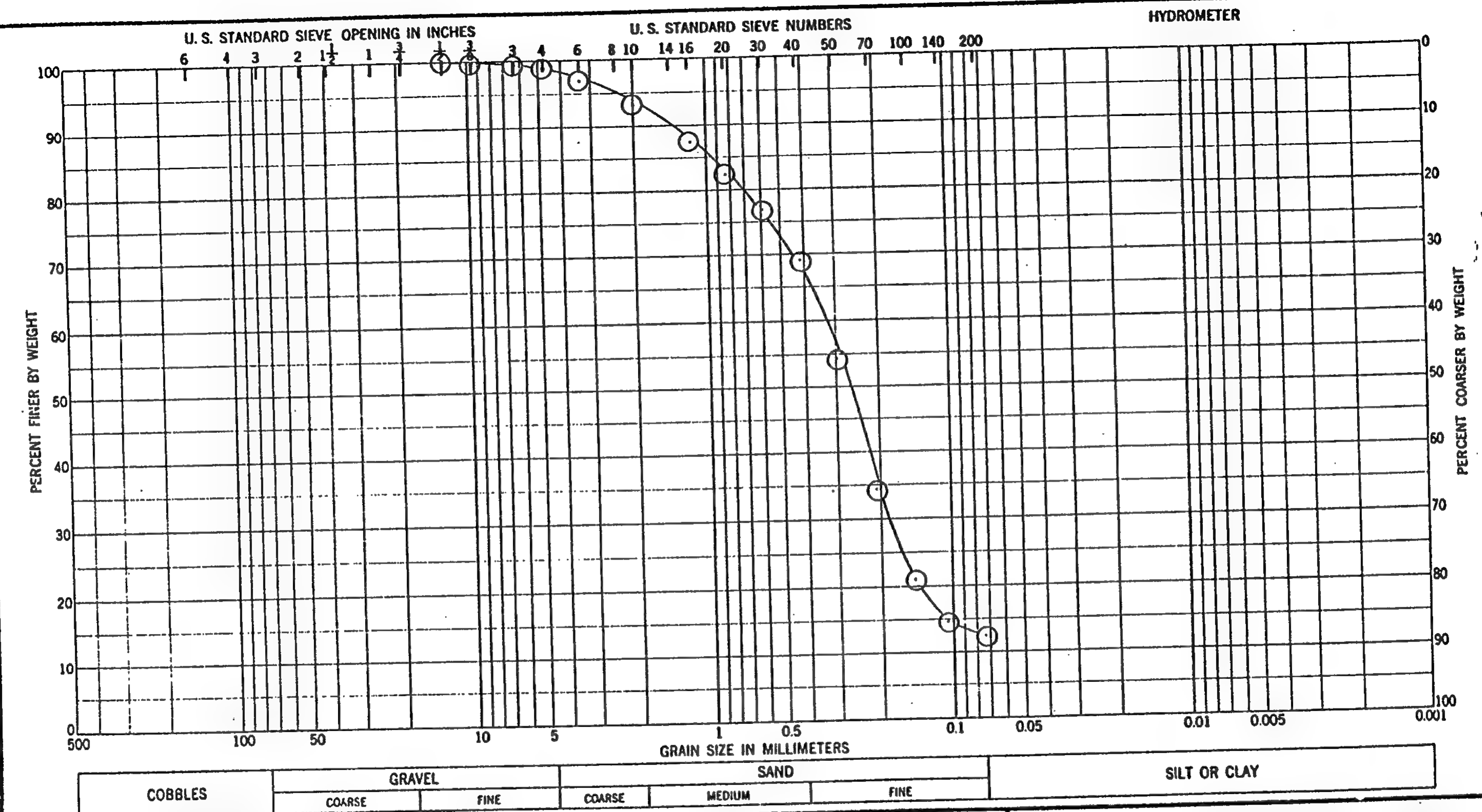
Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A105



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
9	40.0-41.5	SILTY SAND (SM) TAN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No.: 960

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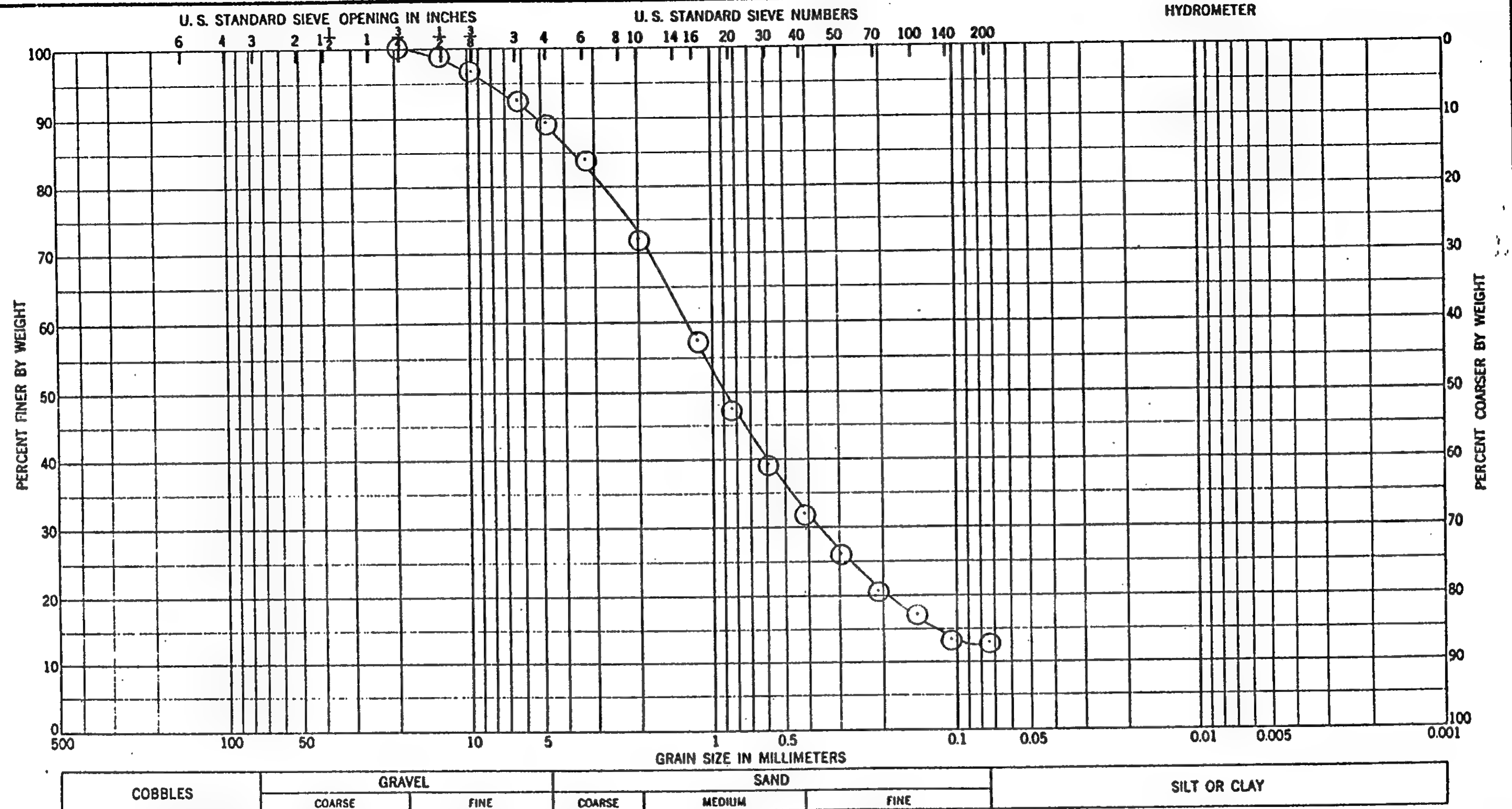
GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A106



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	25.0-26.5	SILTY SAND (SM) WITH GRAVEL				
		BROWN				

Project ROCKY MOUNTAIN ARSENAL

Area

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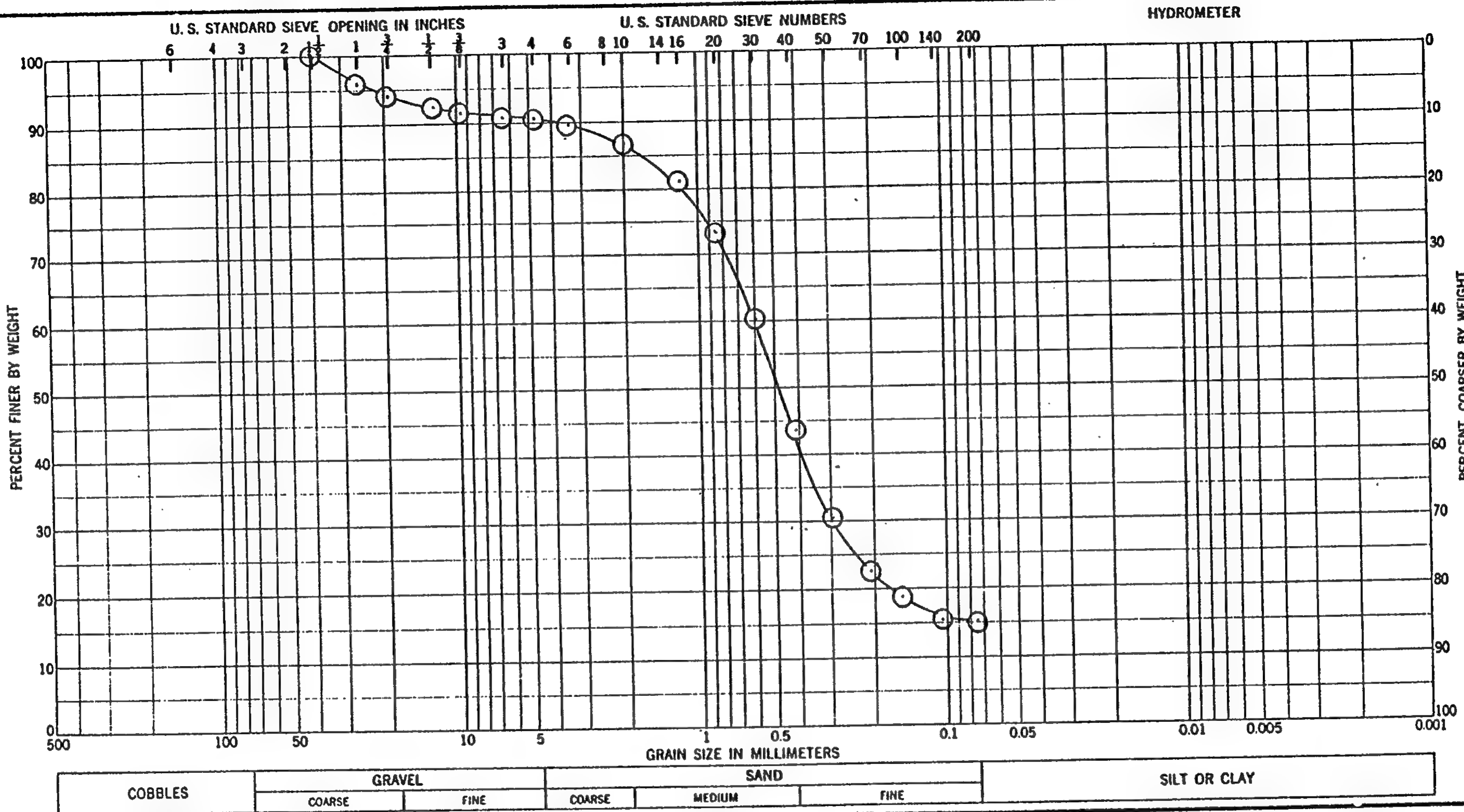
GRADATION CURVES

Results of Sieve Analysis

Plate A107

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	20.0-21.5	SILTY SAND (SM) WITH GRAVEL BROWN				

Project ROCKY MOUNTAIN ARSENAL

Area

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Date 2 JULY 79

GRADATION CURVES

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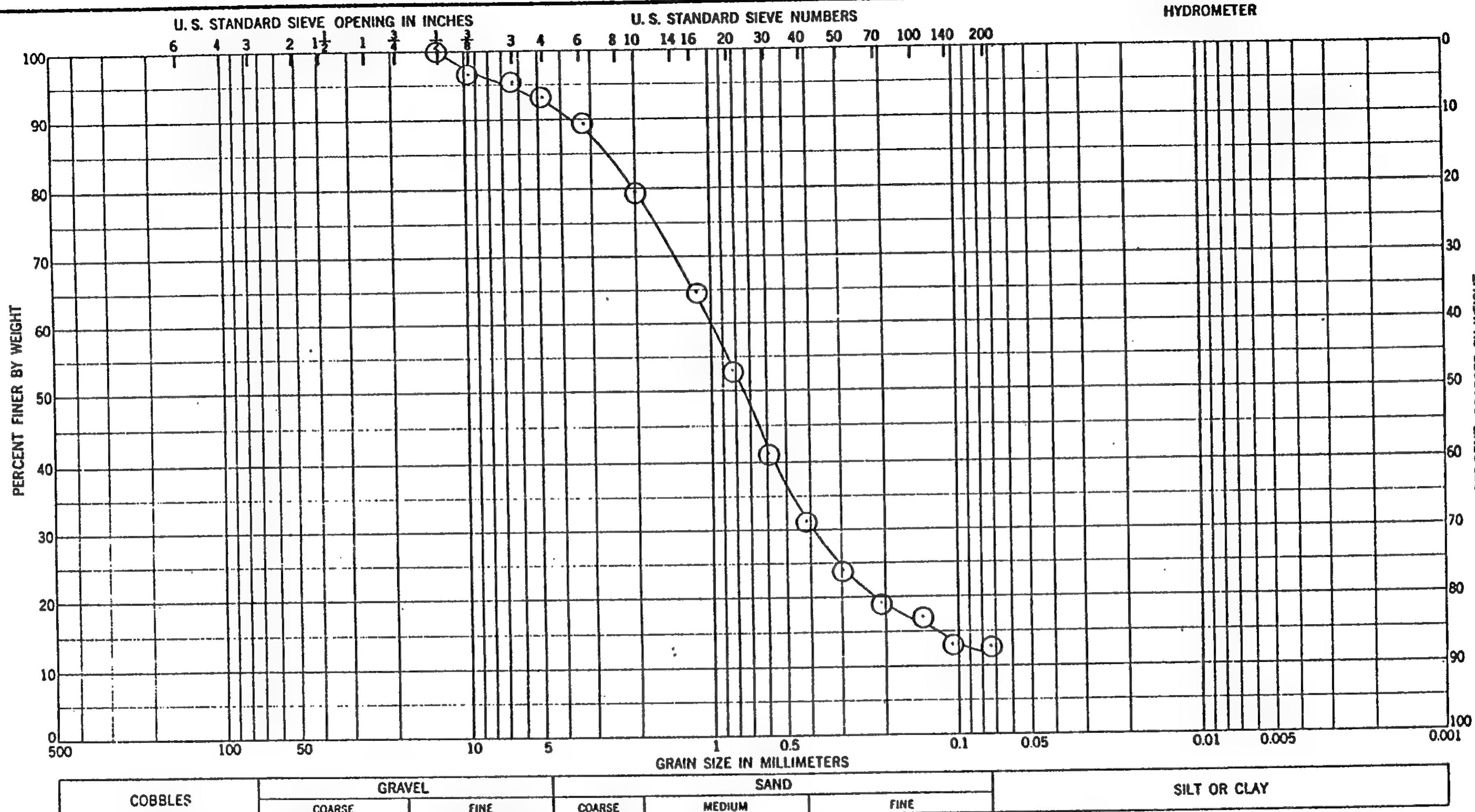
Results of Sieve Analysis

Plate A108



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	CLAYEY SAND (SC) WITH GRAVEL BROWN		34	16	18

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 963

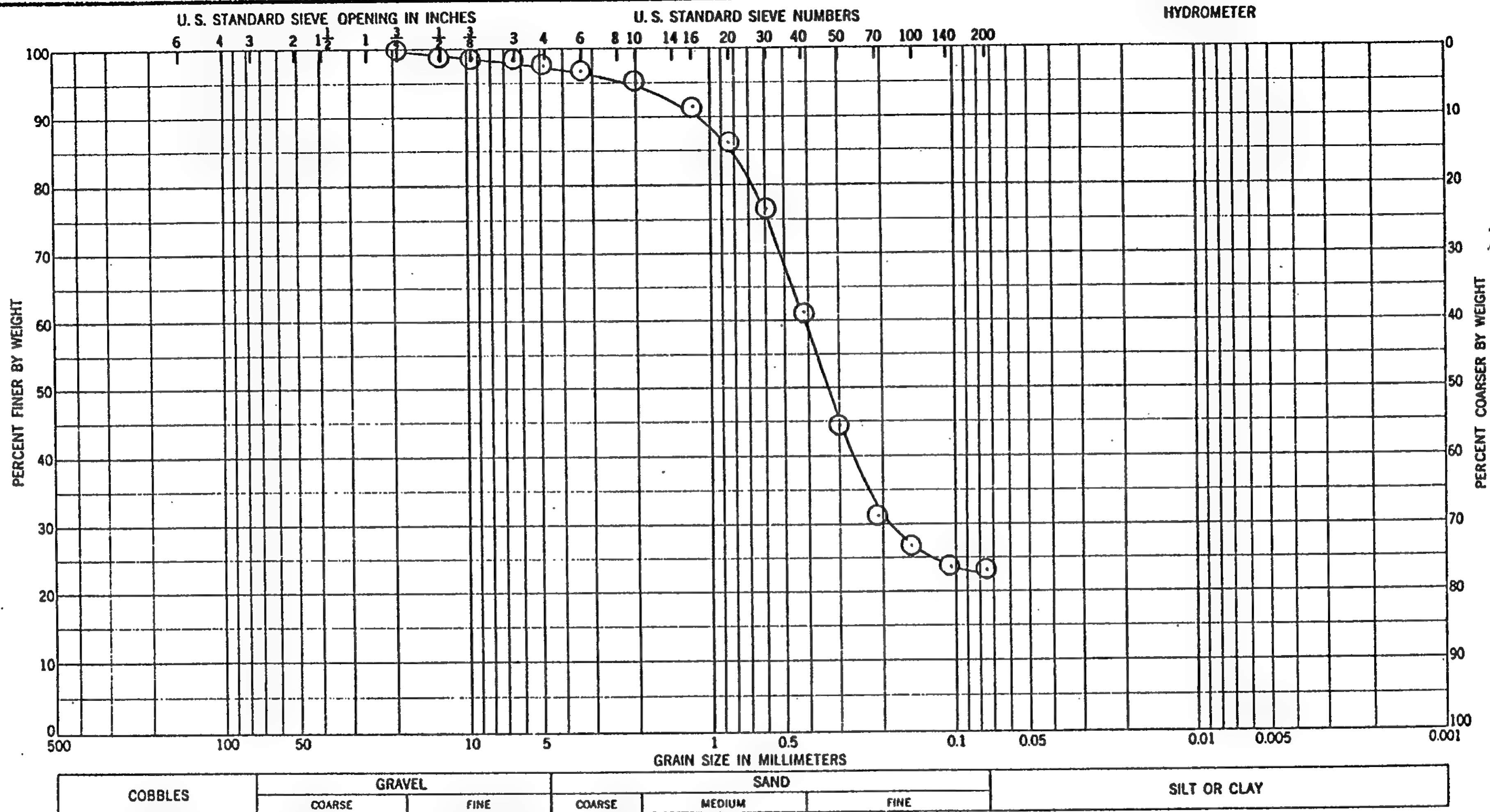
Date 10 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A109



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	25.0-26.5	CLAYEY SAND (SC) BROWN		26	14	12

Project ROCKY MOUNTAIN ARSENAL

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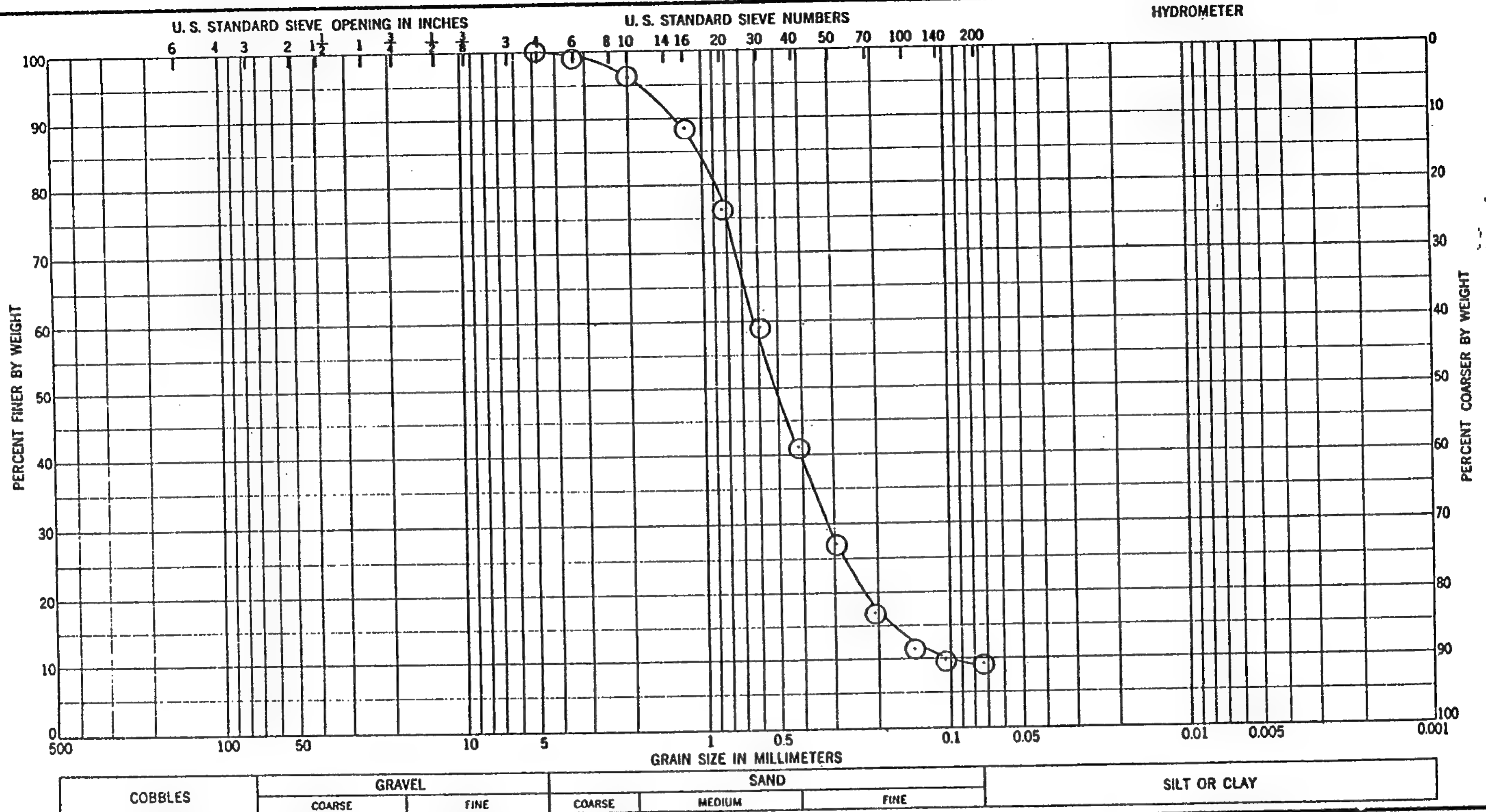
GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	25.0-26.5	SILTY SAND (SW-SM) BROWN				

Project ROCKY MOUNTAIN ARSENAL

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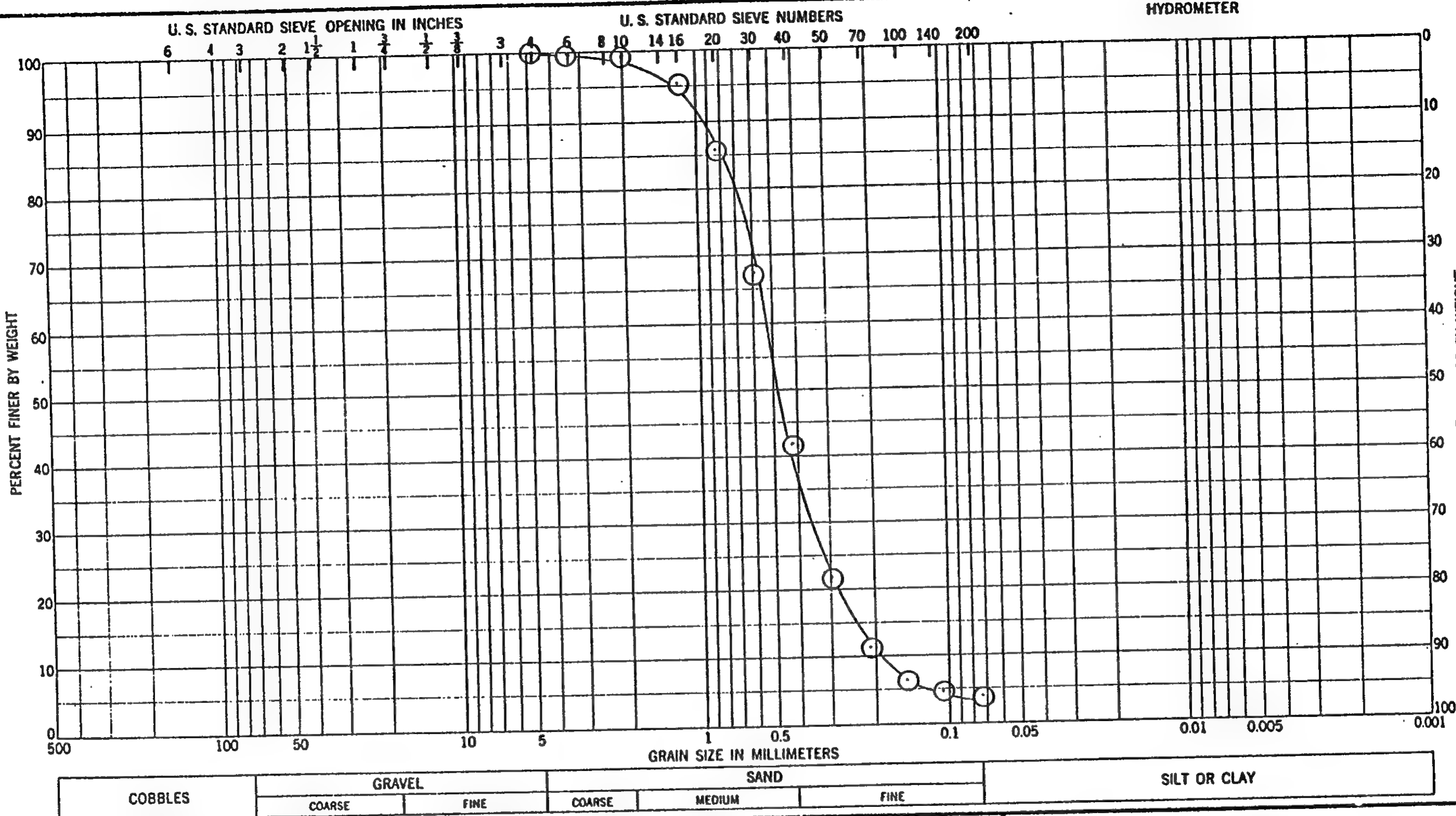
Date 11 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A111

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	19.0-20.5	SAND (SP) TAN				

Project: ROCKY MOUNTAIN ARSENAL

Area:

Boring No.: 967

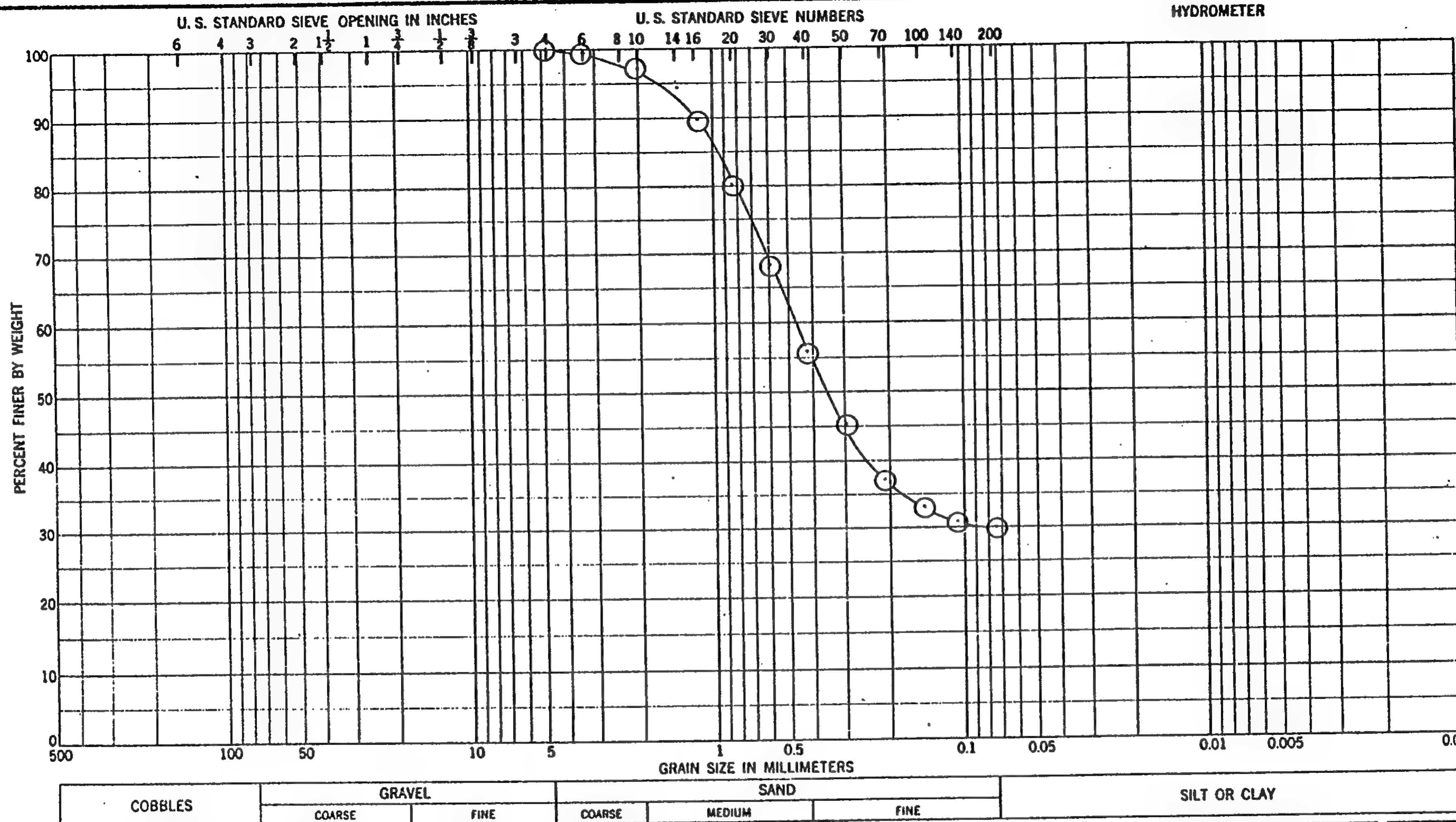
Date: 10 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A112

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	20.0-21.5	CLAYEY SAND (SC) BROWN		31	15	16

GRADATION CURVES

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Boring No.	
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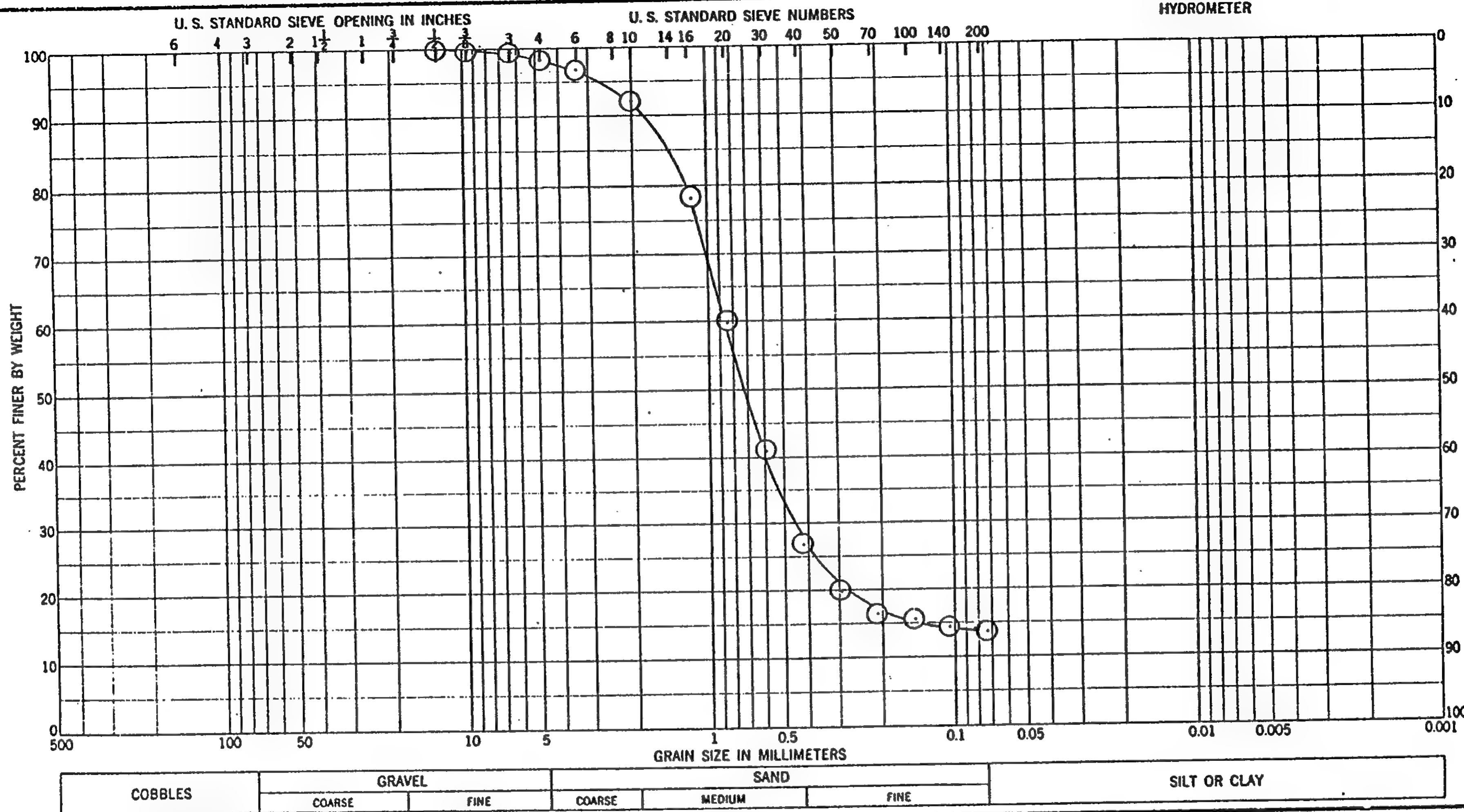
Results of Sieve Analysis

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6	25.0-26.5	SILTY SAND (SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 969

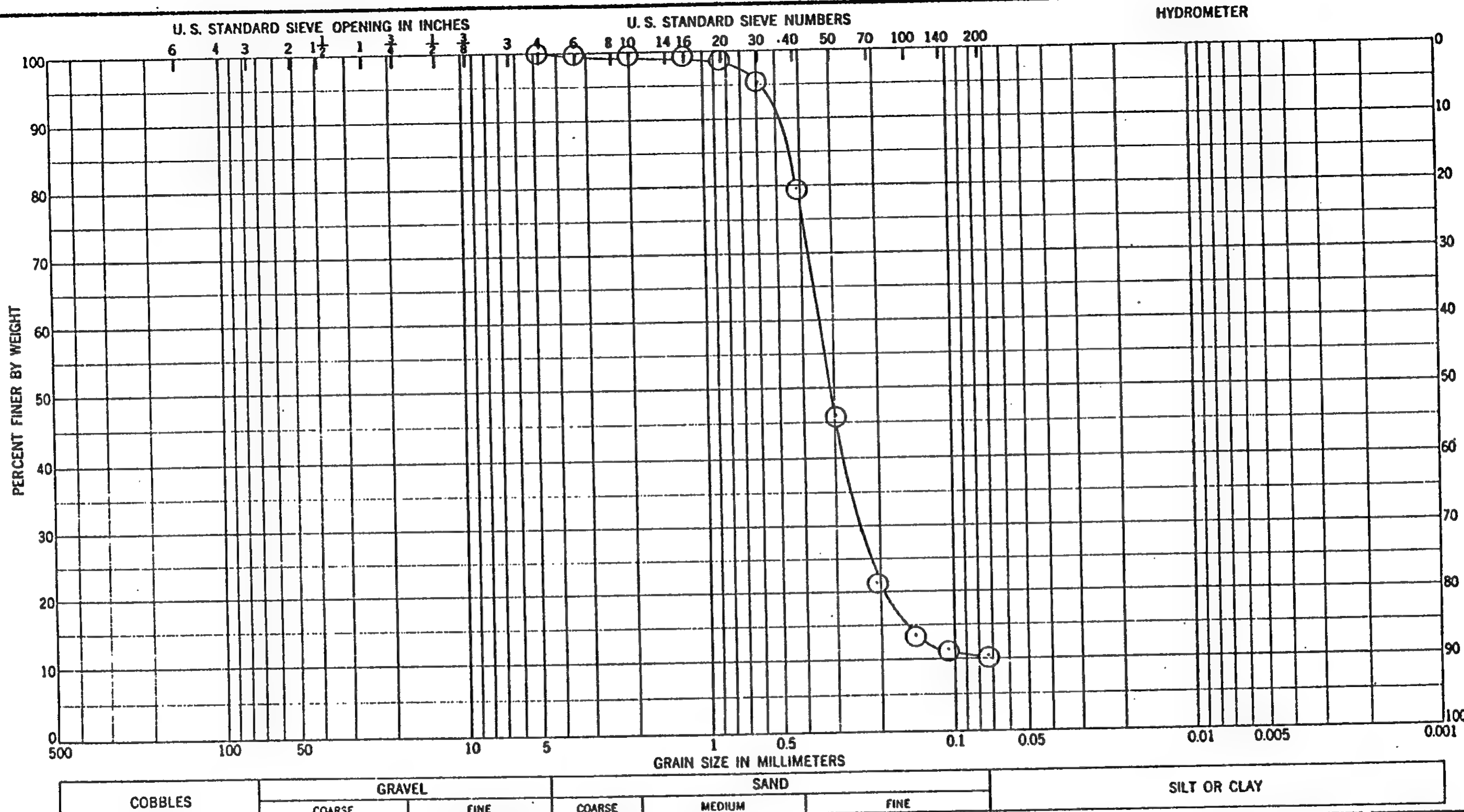
Date 10 JULY 79

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Results of Sieve Analysis

Plate A114



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
16	74.0-74.8	SILTY SAND (SP-SM) TAN				

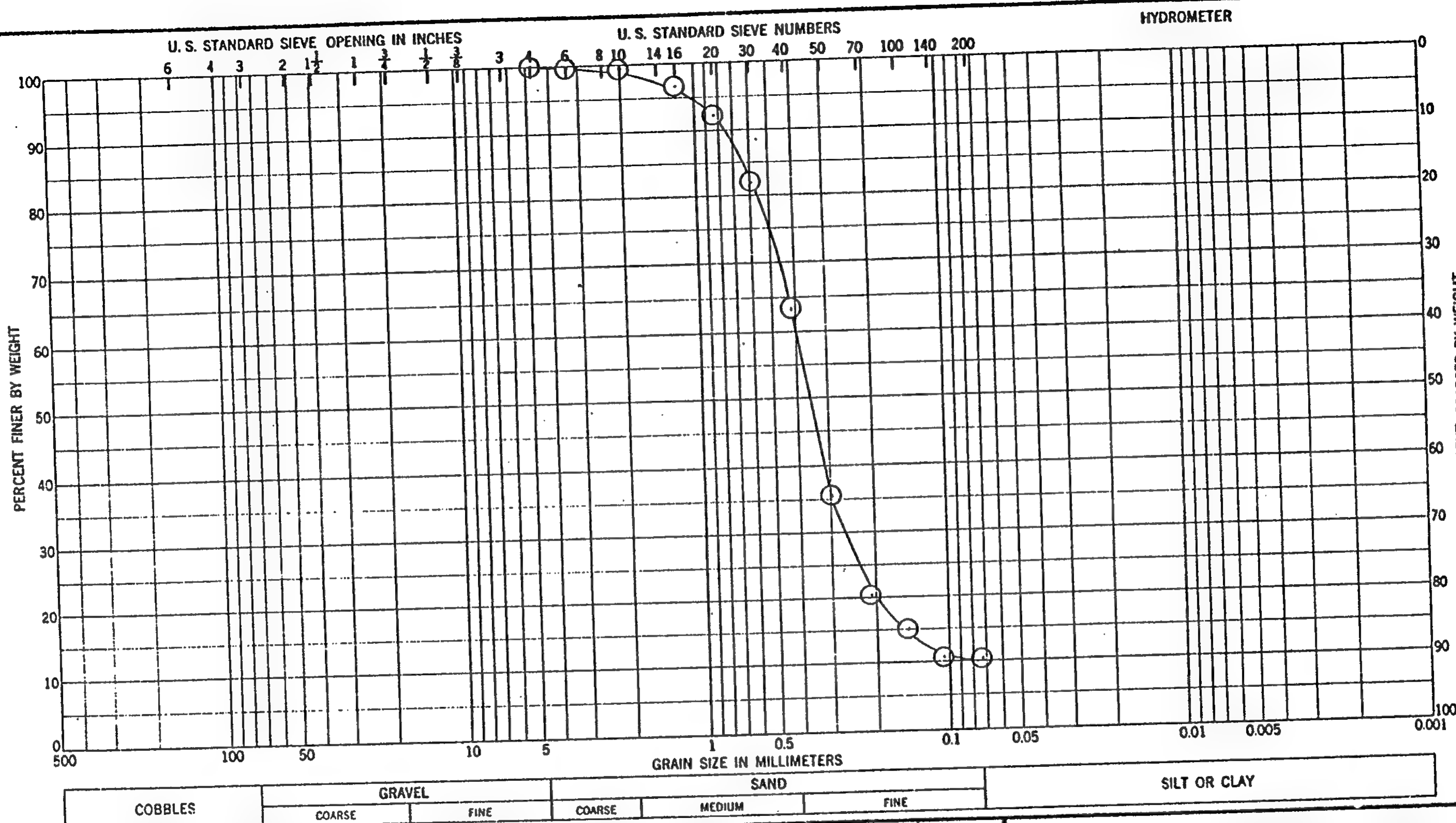
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	970
Date	10 JULY 79

GRADATION CURVES

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A115



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
17	79.0-79.4	SILTY SAND (SP-SM) TAN				

Project ROCKY MOUNTAIN ARSENAL

Area

Boring No. 970

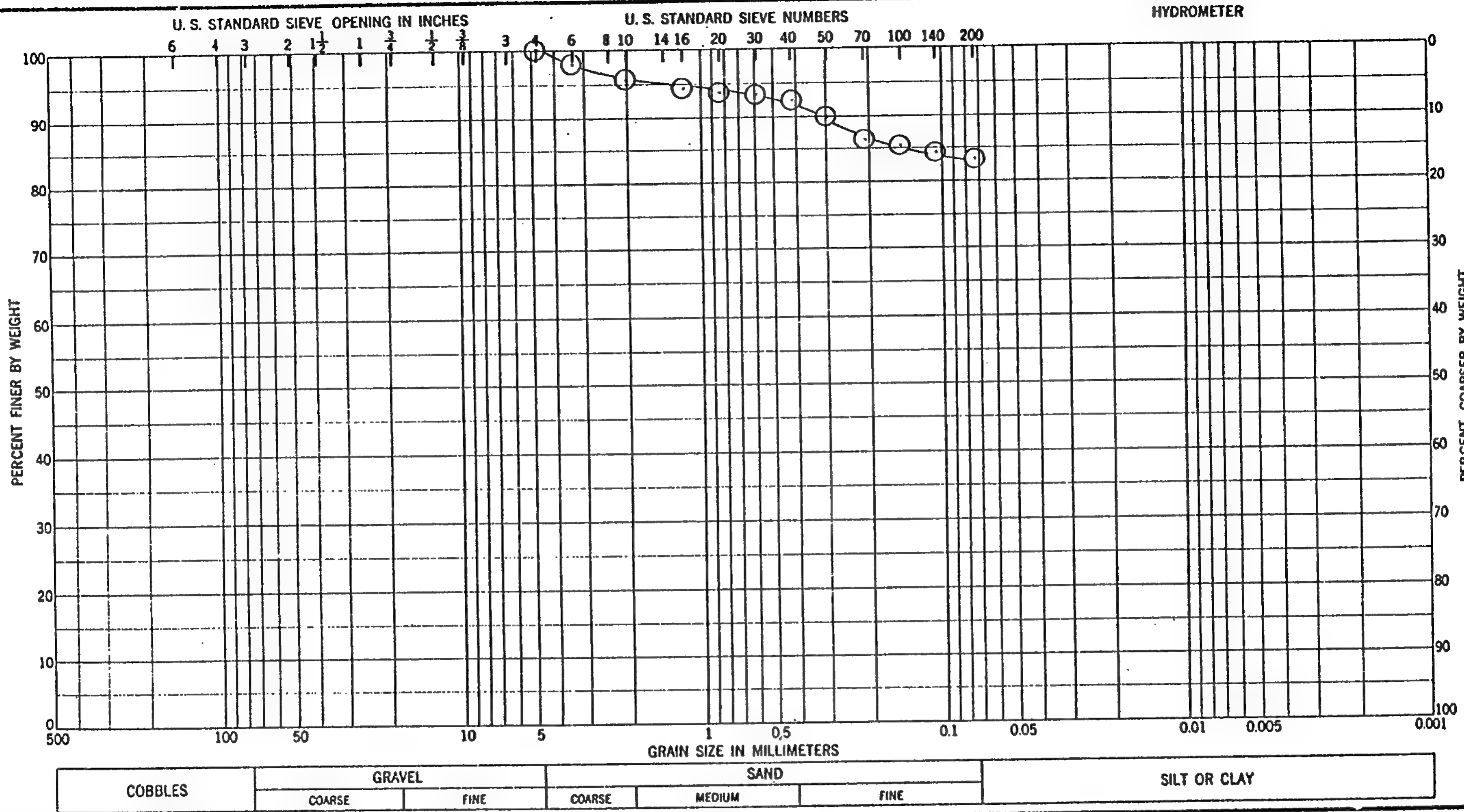
Date 10 JULY 79

GRADATION CURVES

Results of Sieve Analysis

Plate A116

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8	34.0-35.5	SANDY CLAY (CL) BROWN				

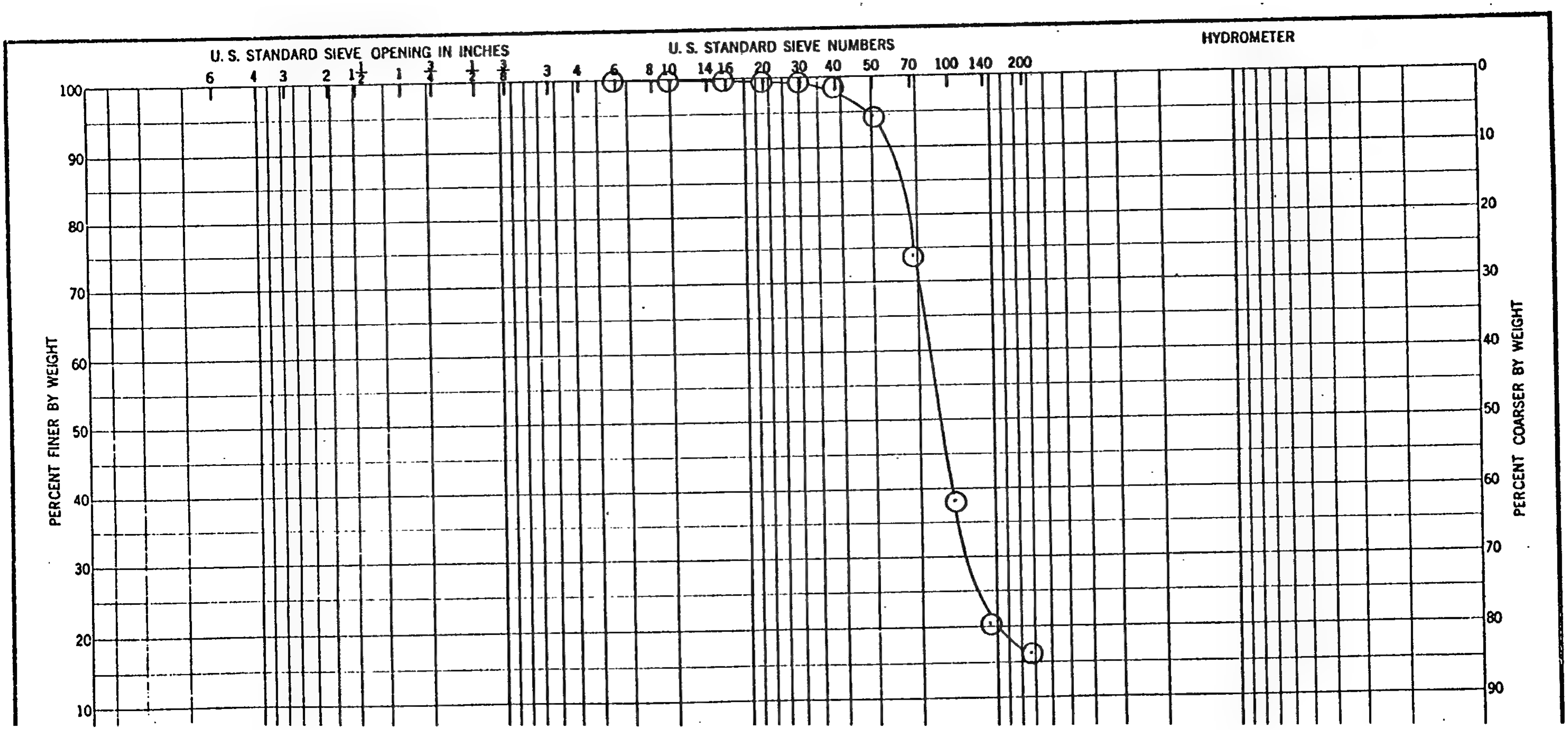
Project	ROCKY MOUNTAIN ARSENAL
Area	
Boring No.	971
Date	10 JULY 79

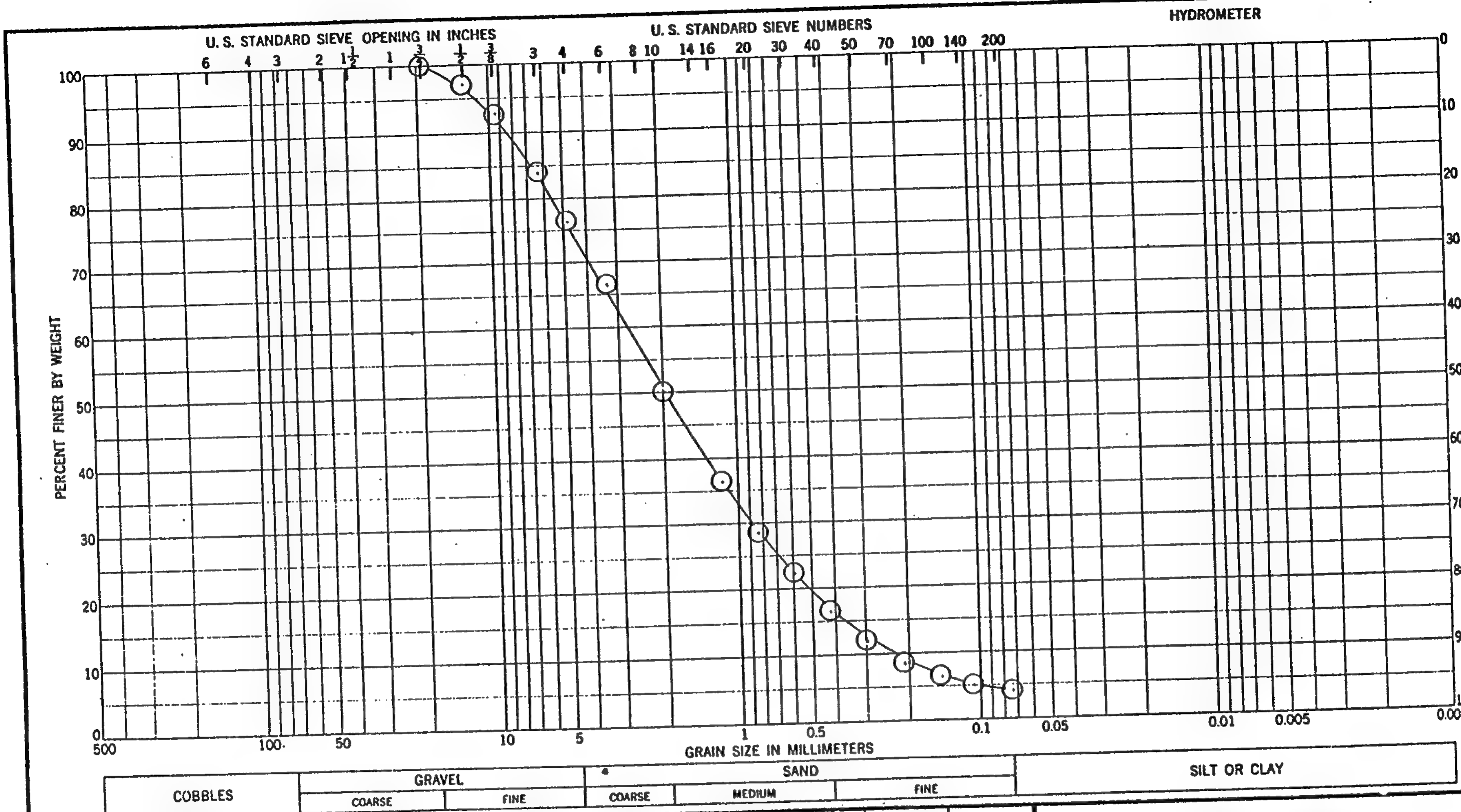
GRADATION CURVES

Results of Sieve Analysis

Plate A117

ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
6 4 3 2 1½ 1 ¾ ½ ⅜
U. S. STANDARD SIEVE NUMBERS
3 4 6 8 10 14 16 20 30 40 50 70 100 140 200
HYDROMETER
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10
PERCENT COARSER BY WEIGHT
0 10 20 30 40 50 60 70 80 90



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
10	44.0-45.5	GRAVELLY SAND (SW) BROWN				

GRADATION CURVES

Project: ROCKY MOUNTAIN ARSENAL

Area:

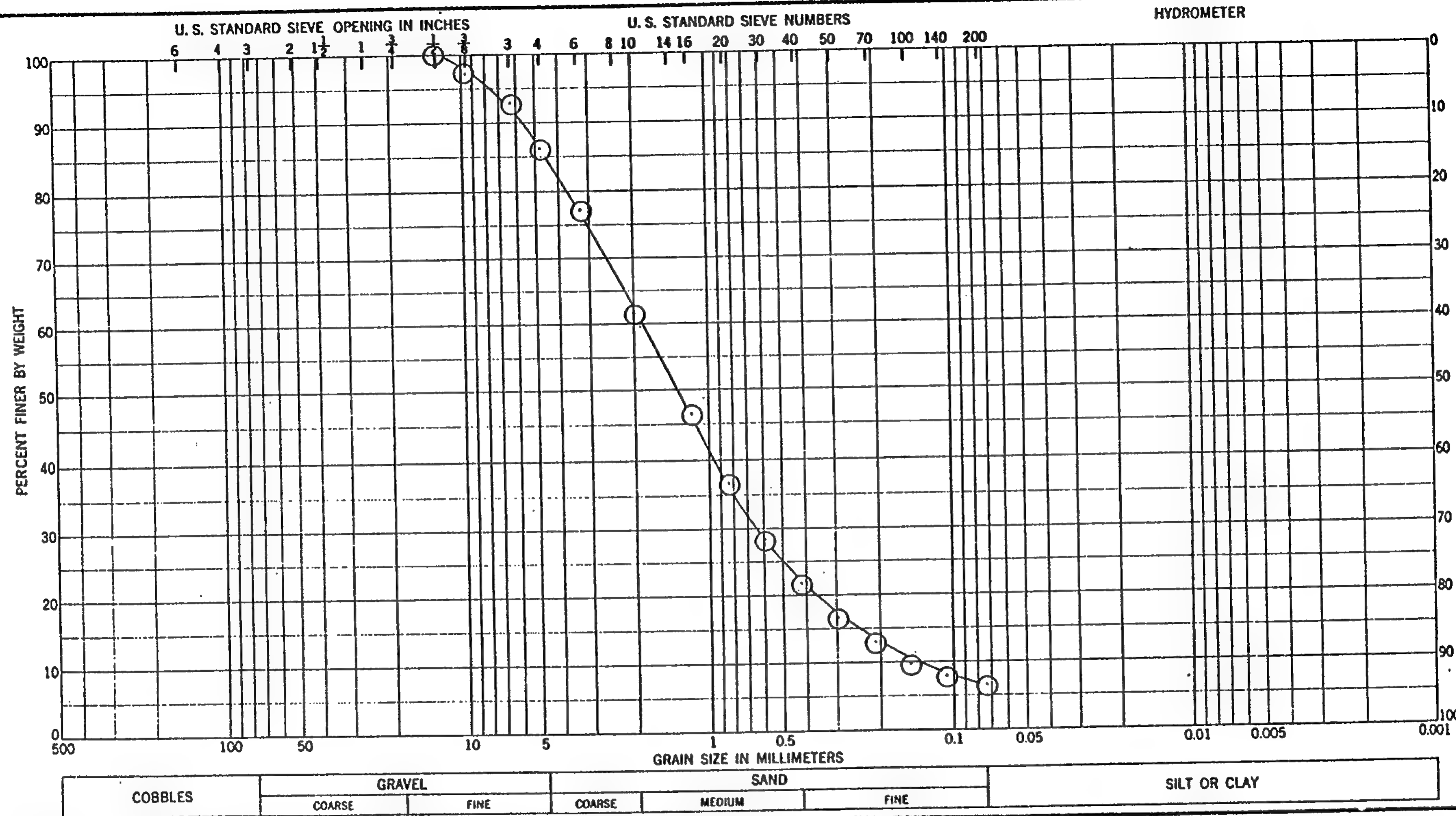
Boring No.: 973

Date: 11 JULY 79

Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

Plate A119



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
5	41.0-42.5	GRAVELLY SILTY SAND (SW-SM) TAN				

GRADATION CURVES

Project: ROCKY MOUNTAIN ARSENAL

Area:

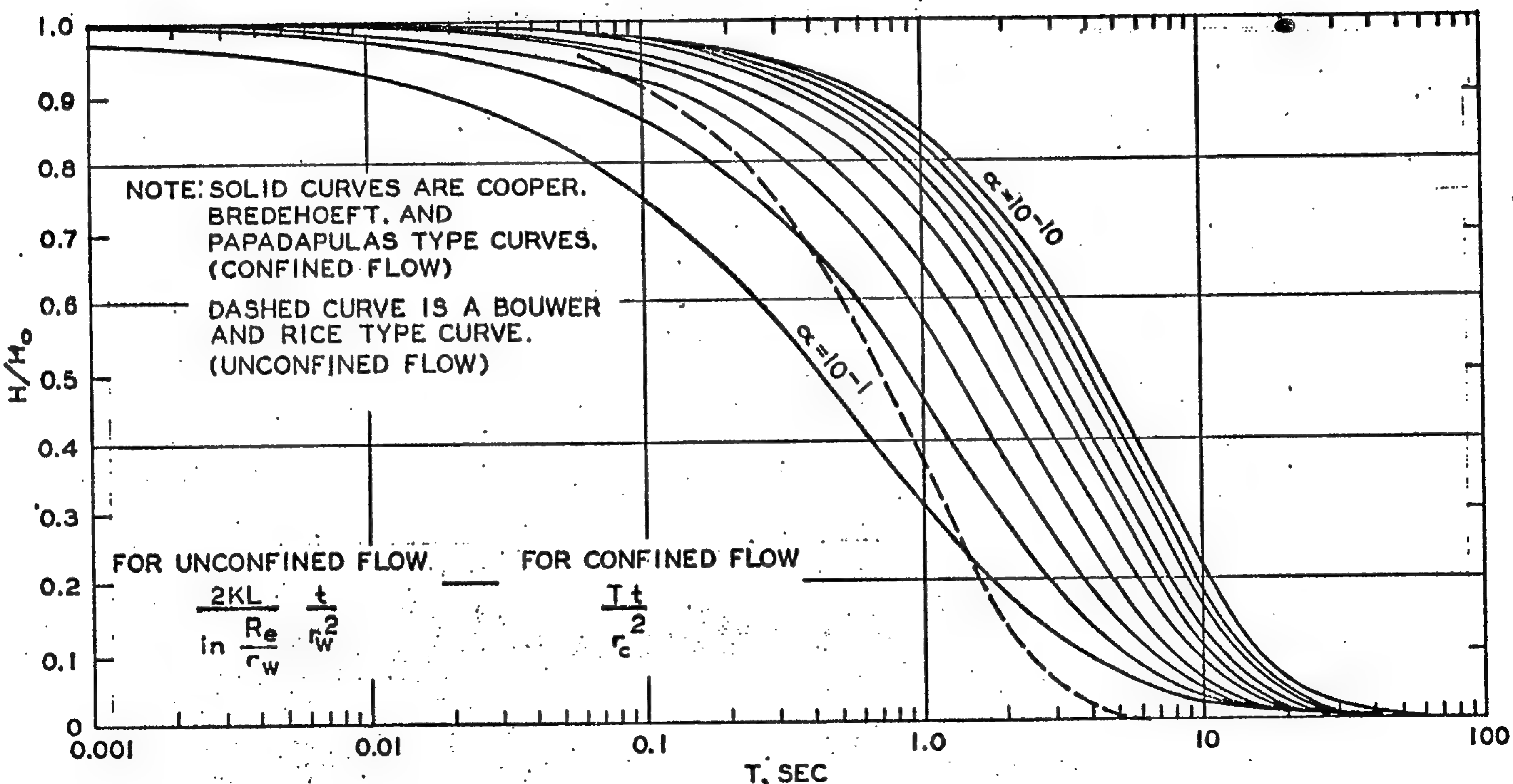
Boring No. 974

Date: 3 JULY 79

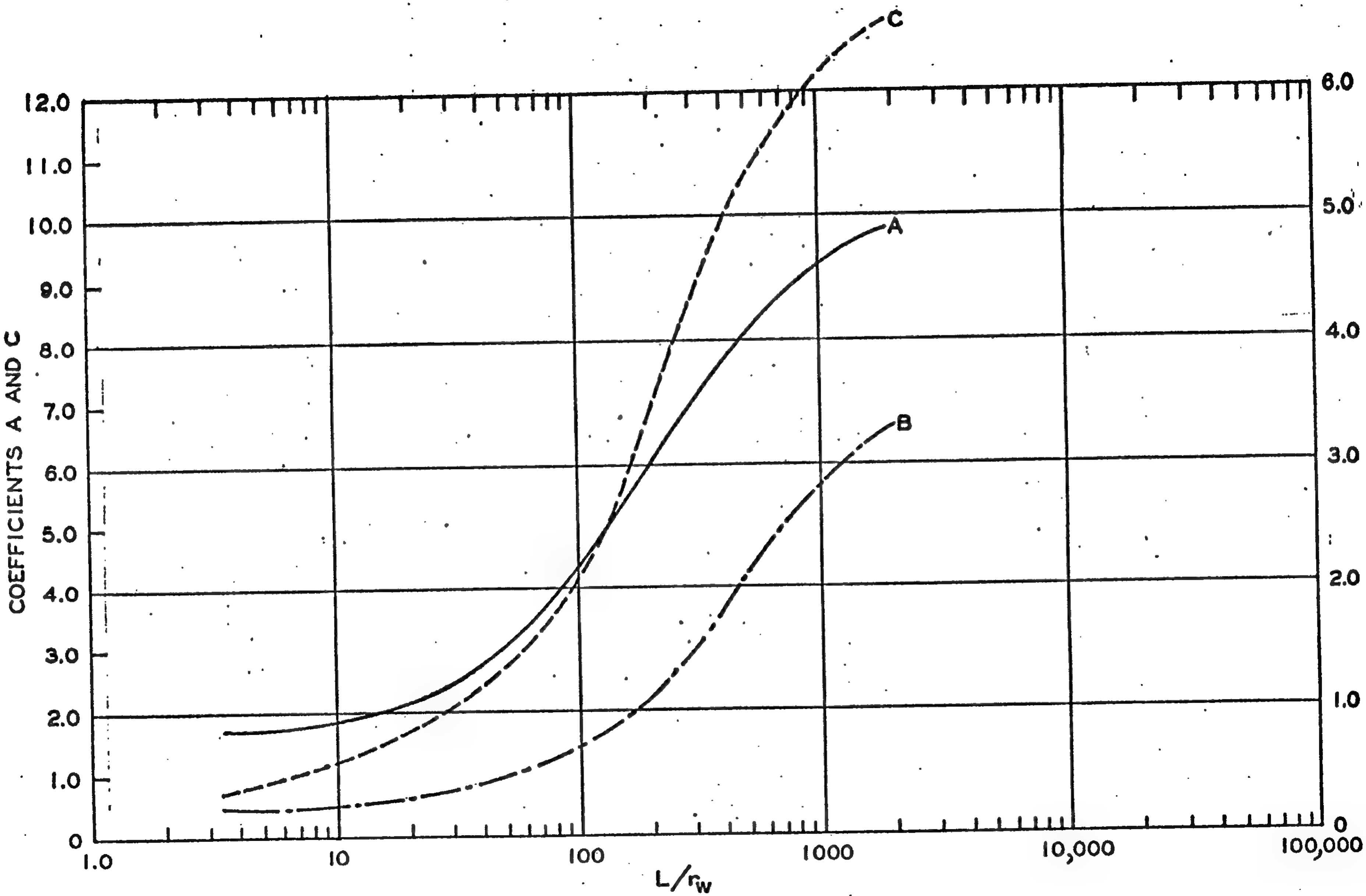
Results of Sieve Analysis

ENG FORM 1 MAY 63 2087

APPENDIX B: FIELD PERMEABILITY CURVES

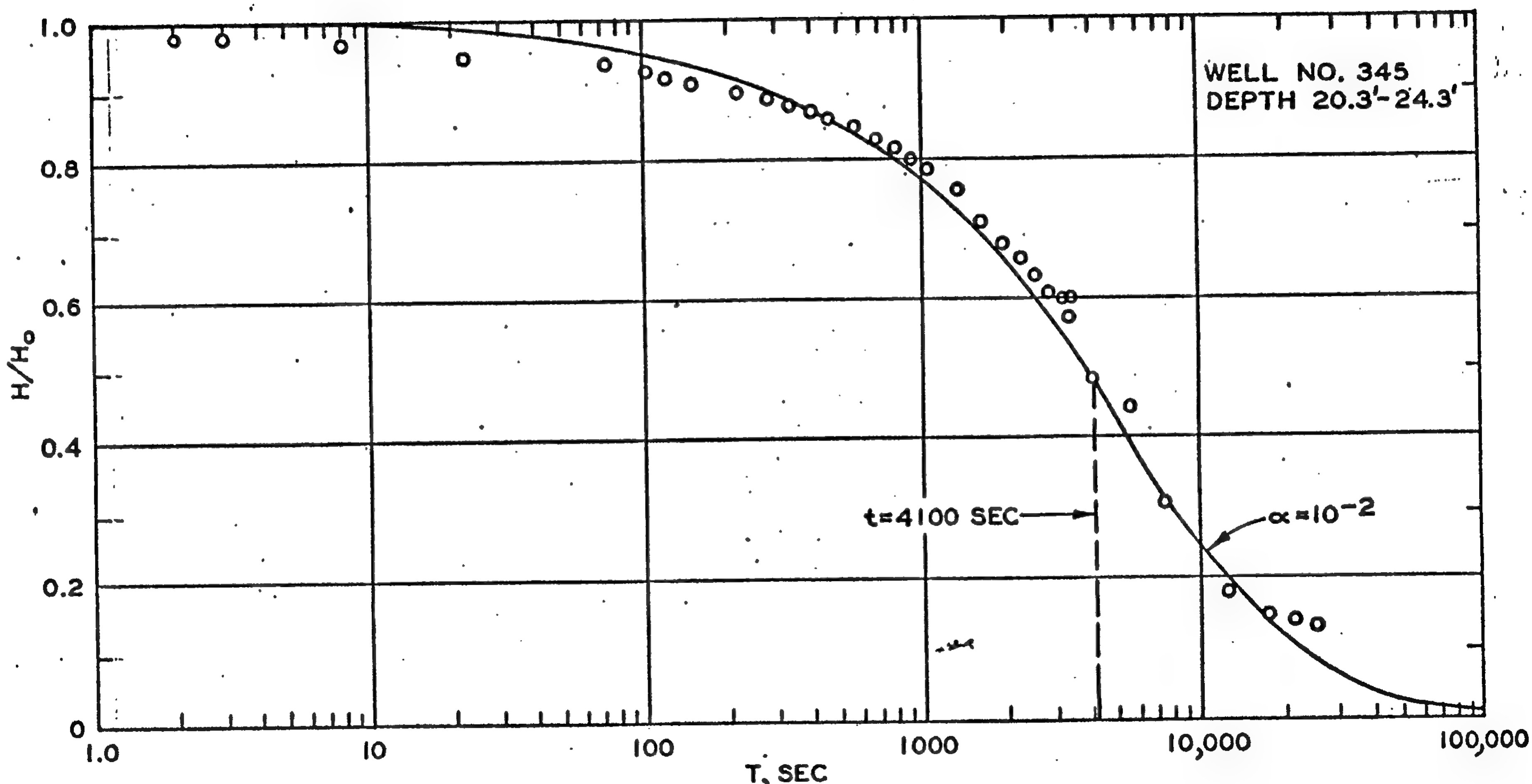


Slug Test Analysis Type Curves



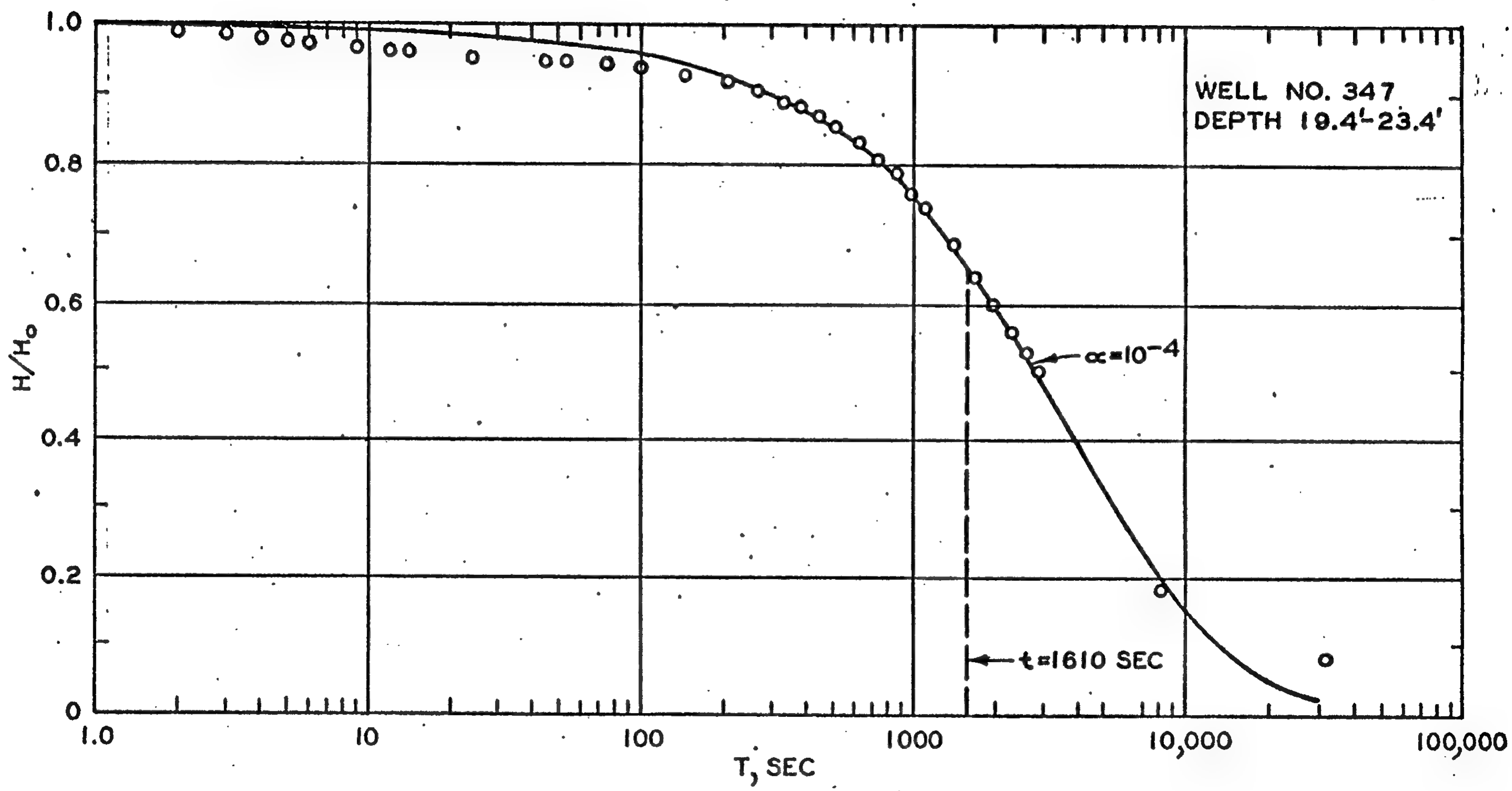
Curves Relating Coefficients A, B, and C to L/r_w

WELL # 345
DEPTH 20.3'-24.3'



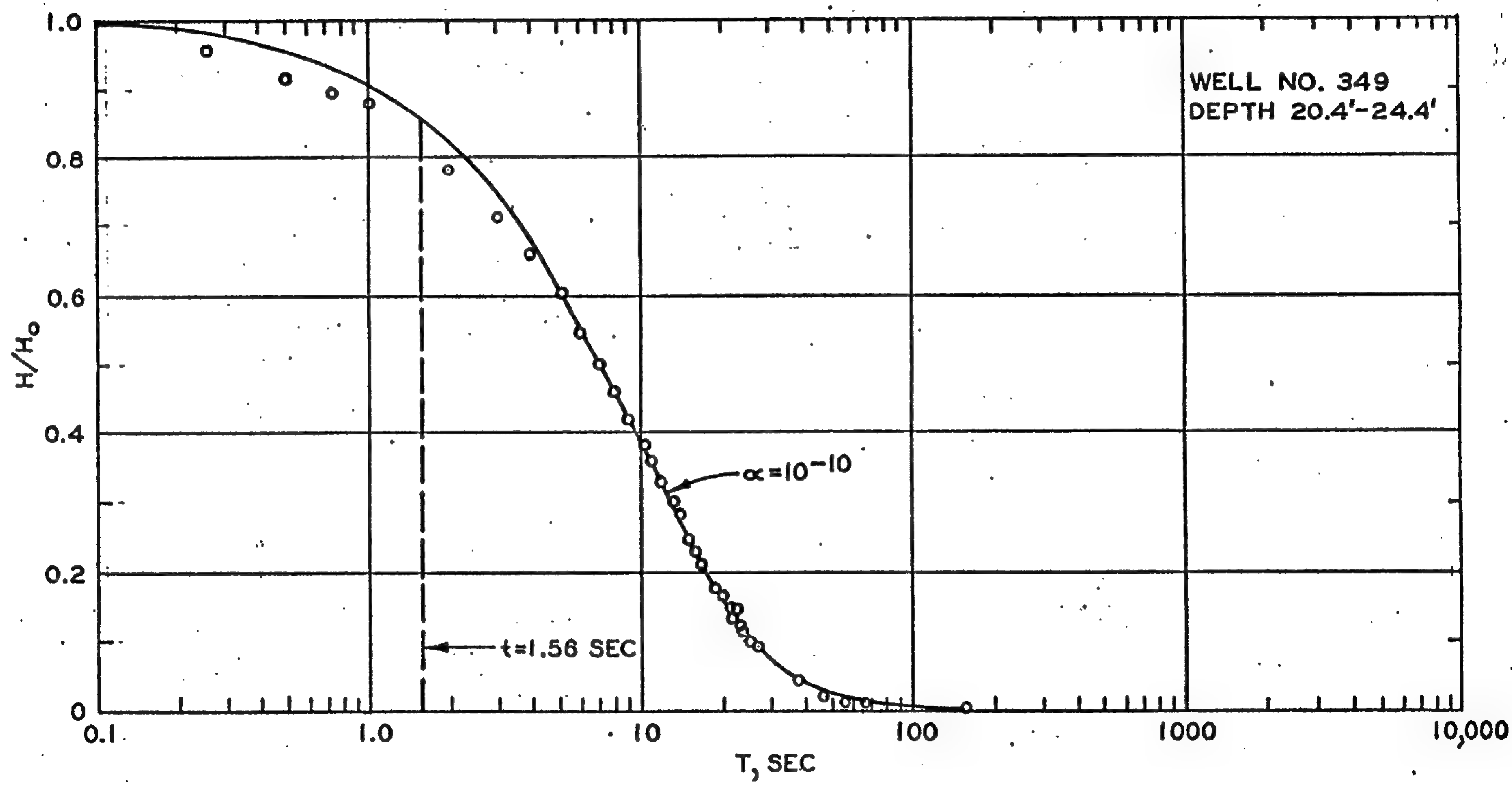
Field Permeability Test Data
with Type Curve

WELL #347
DEPTH 19.4'-23.4'



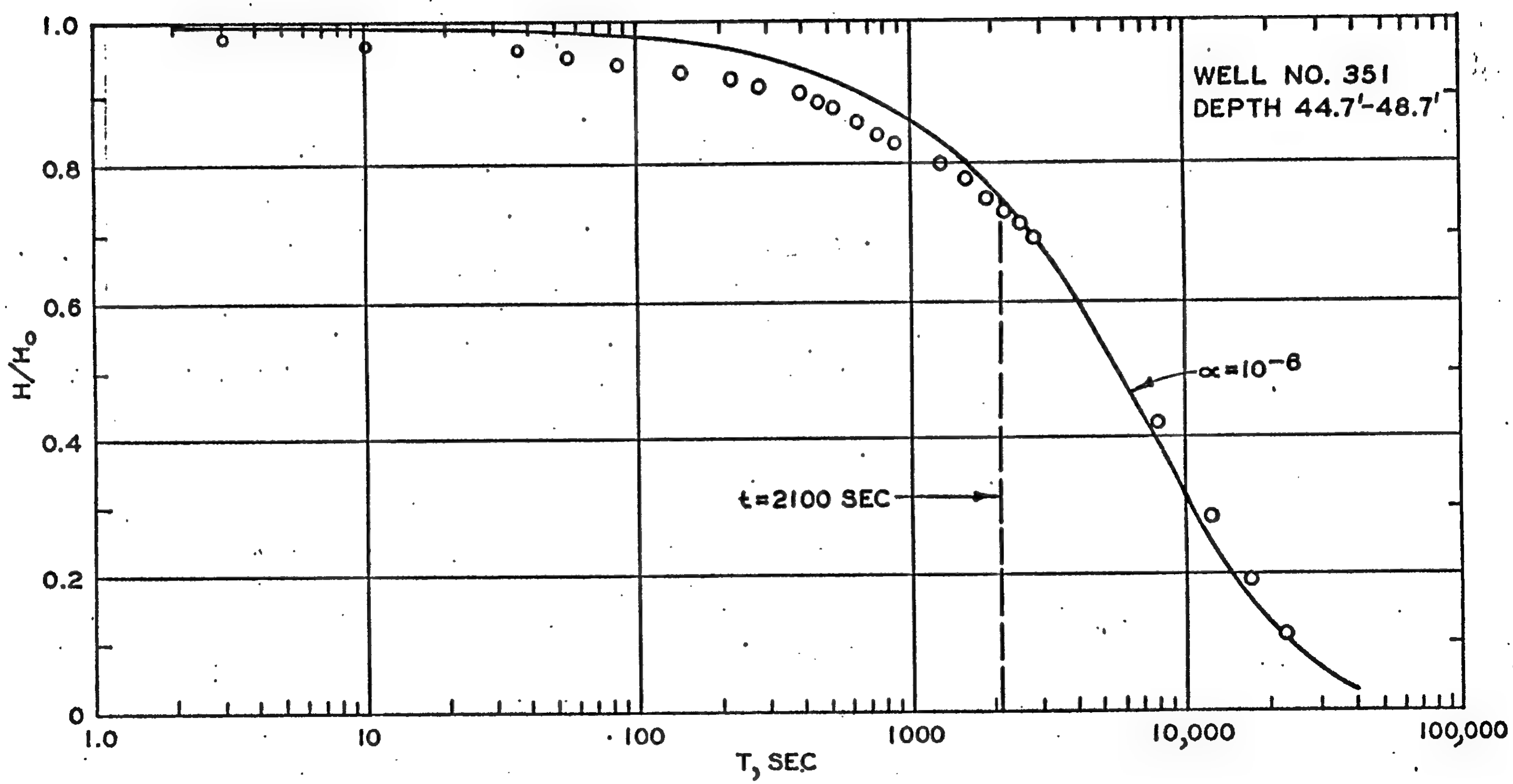
Field Permeability Test Data
with Type Curve

WELL # 349
DEPTH 20.4'-24.4'



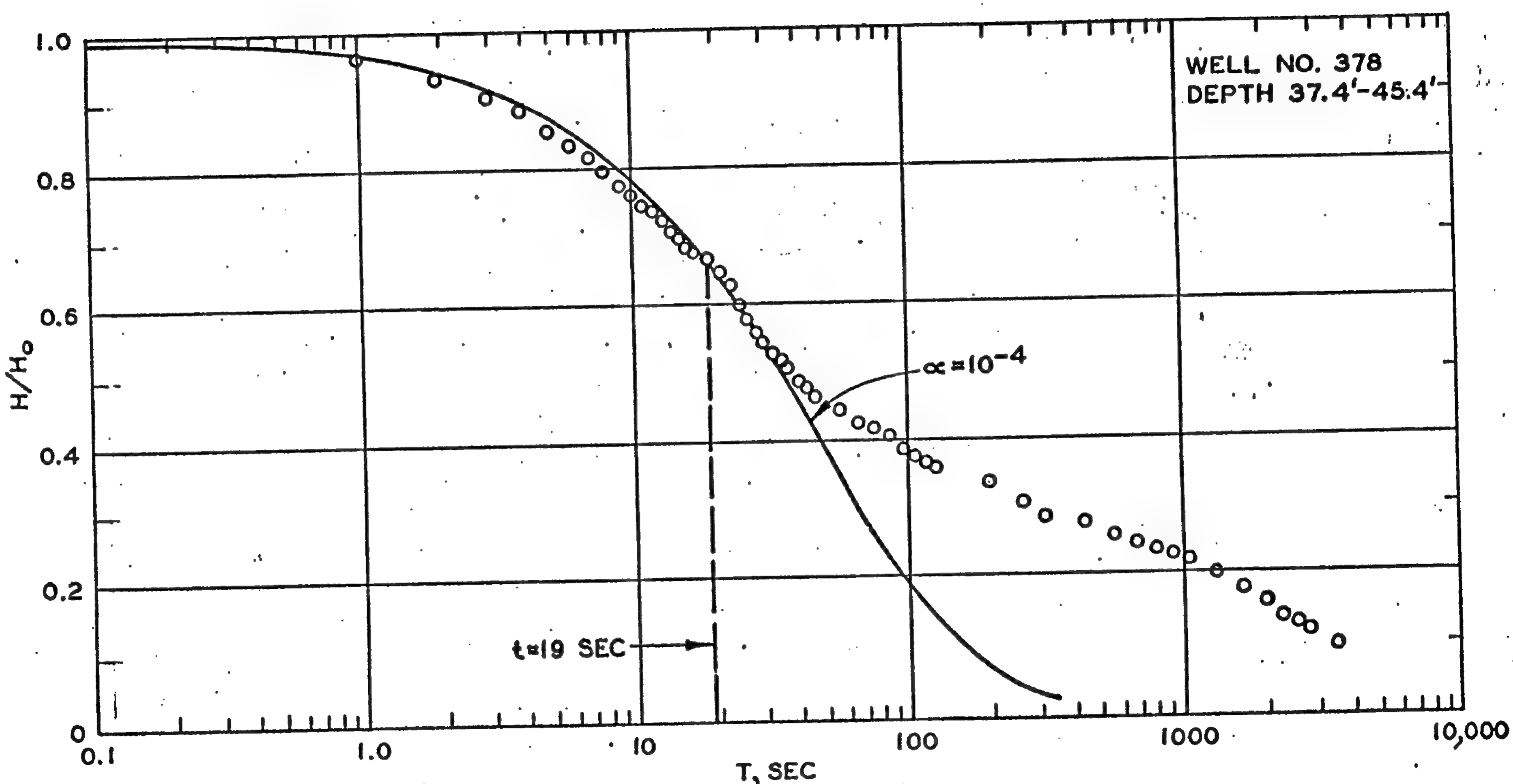
Field Permeability Test Data
with Type Curve

Well #351
Depth 44.7-48.7

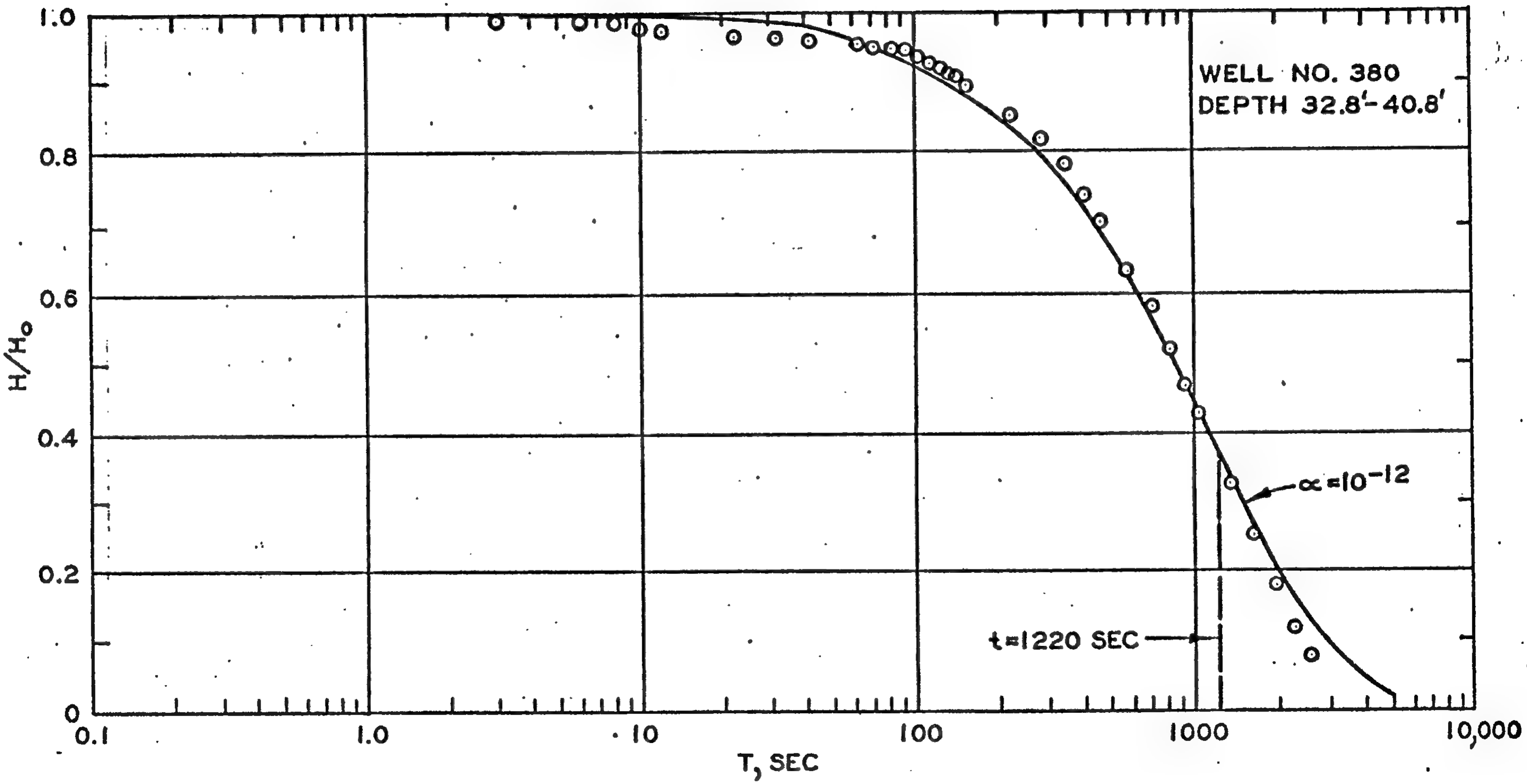


Field Permeability Test Data
with Type Curve

WELL NO. 378
DEPTH 37.8' - 4...

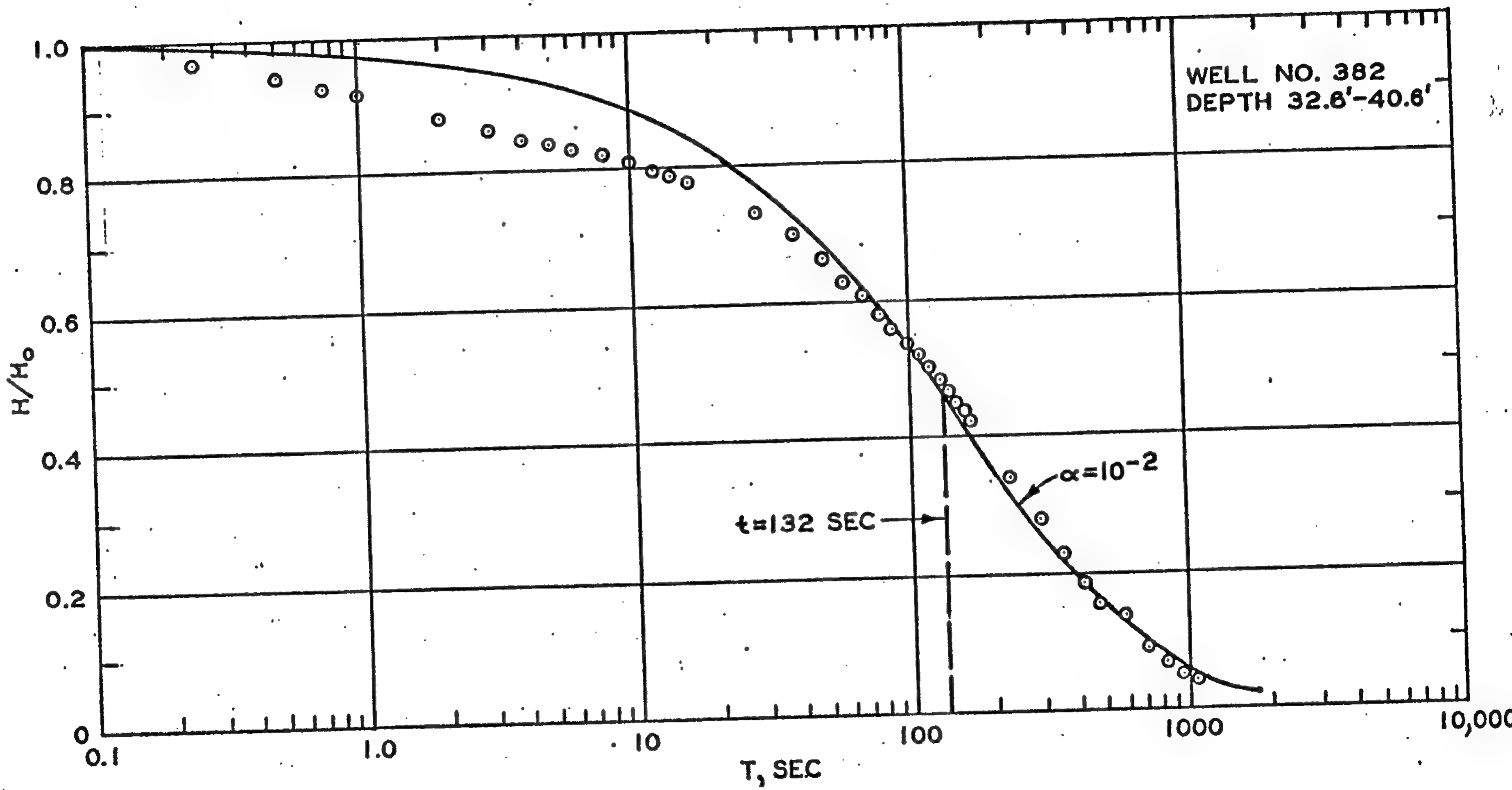


Field Permeability Test Data
with Type Curve



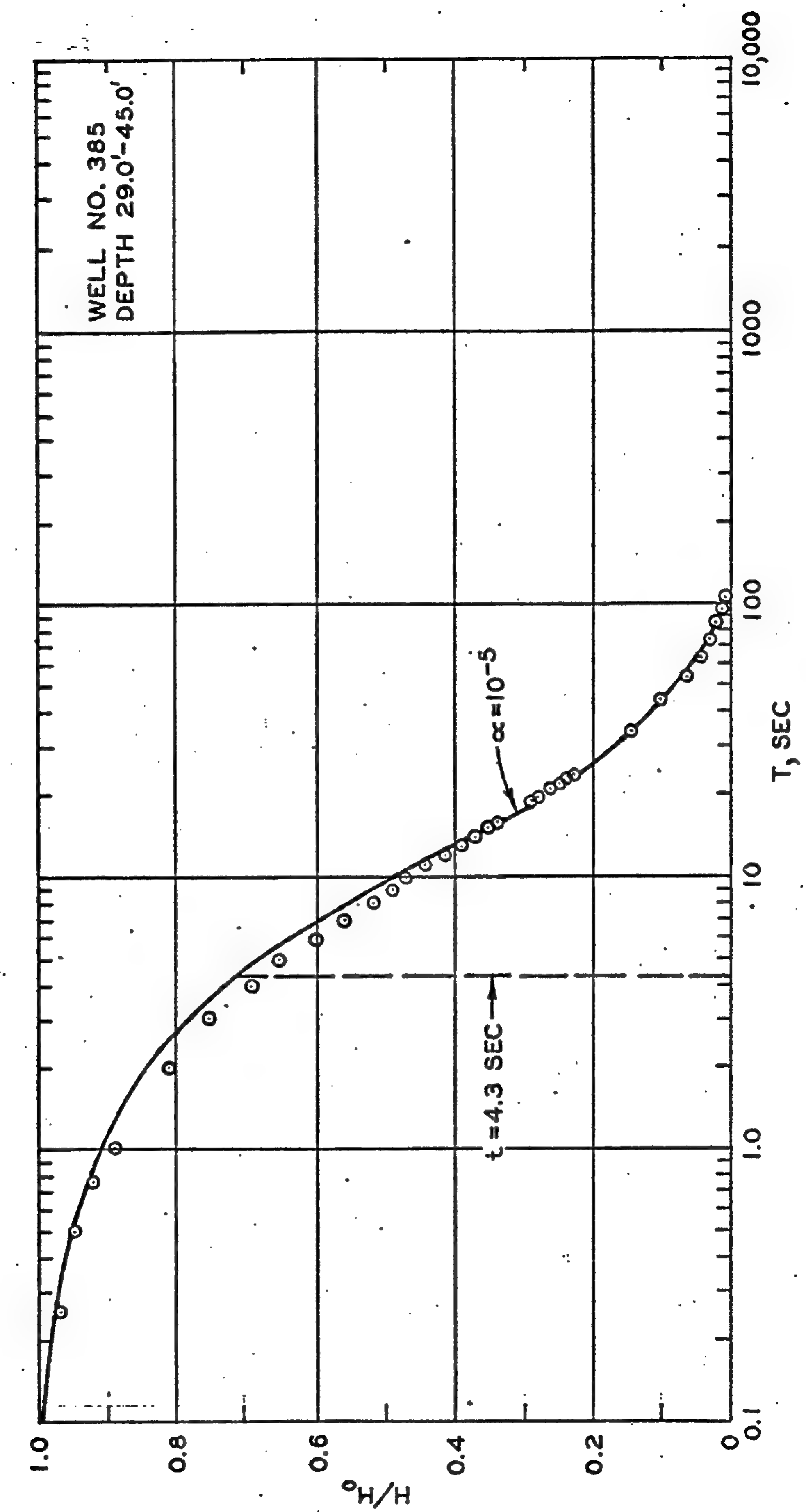
Field Permeability Test Data
with Type Curve

WELL 382
DEPTH 32.6-40.6



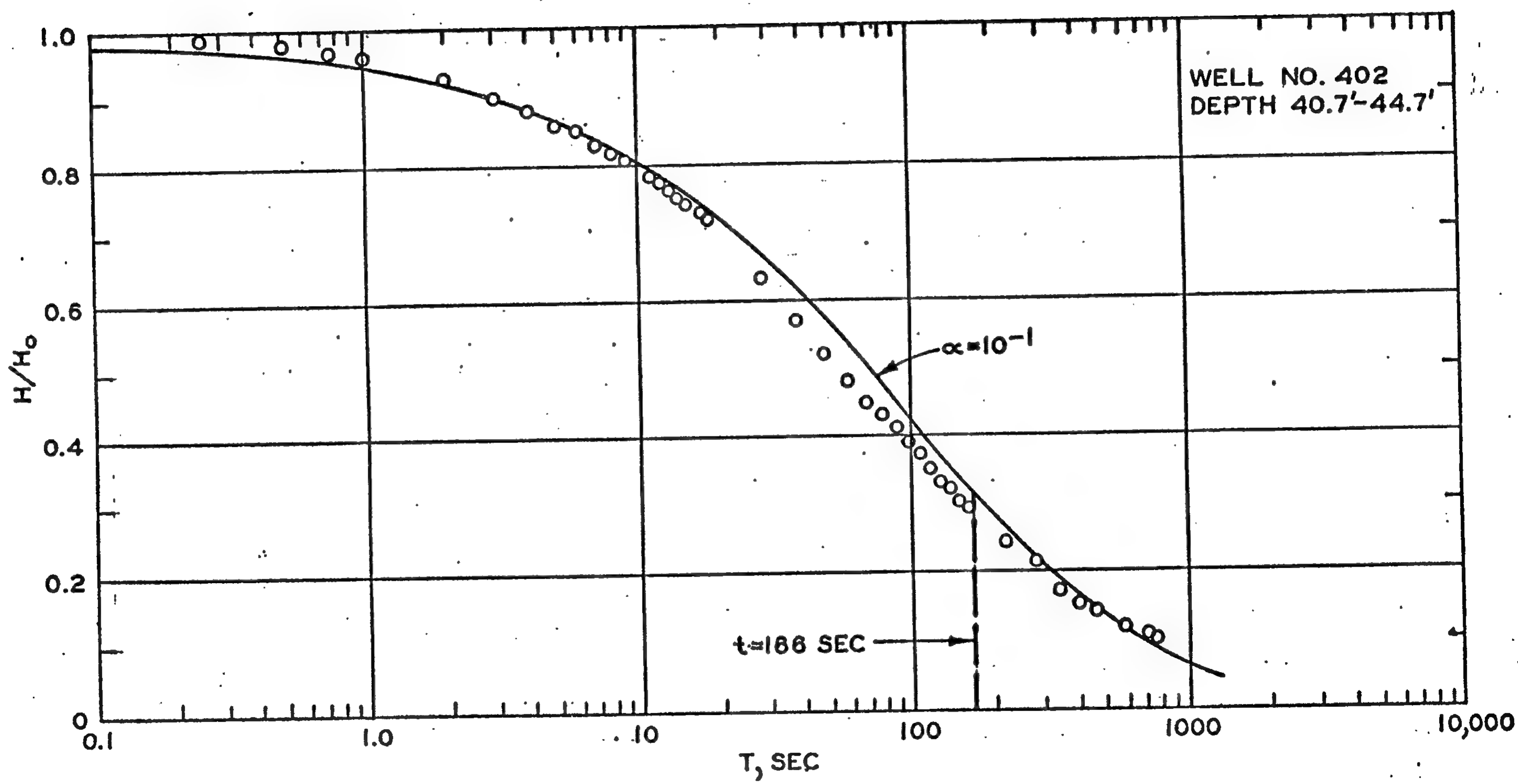
Field Permeability Test Data
with Type Curve

KMA SLUG ?
WELL #385
DEPTH 29.0-45.0



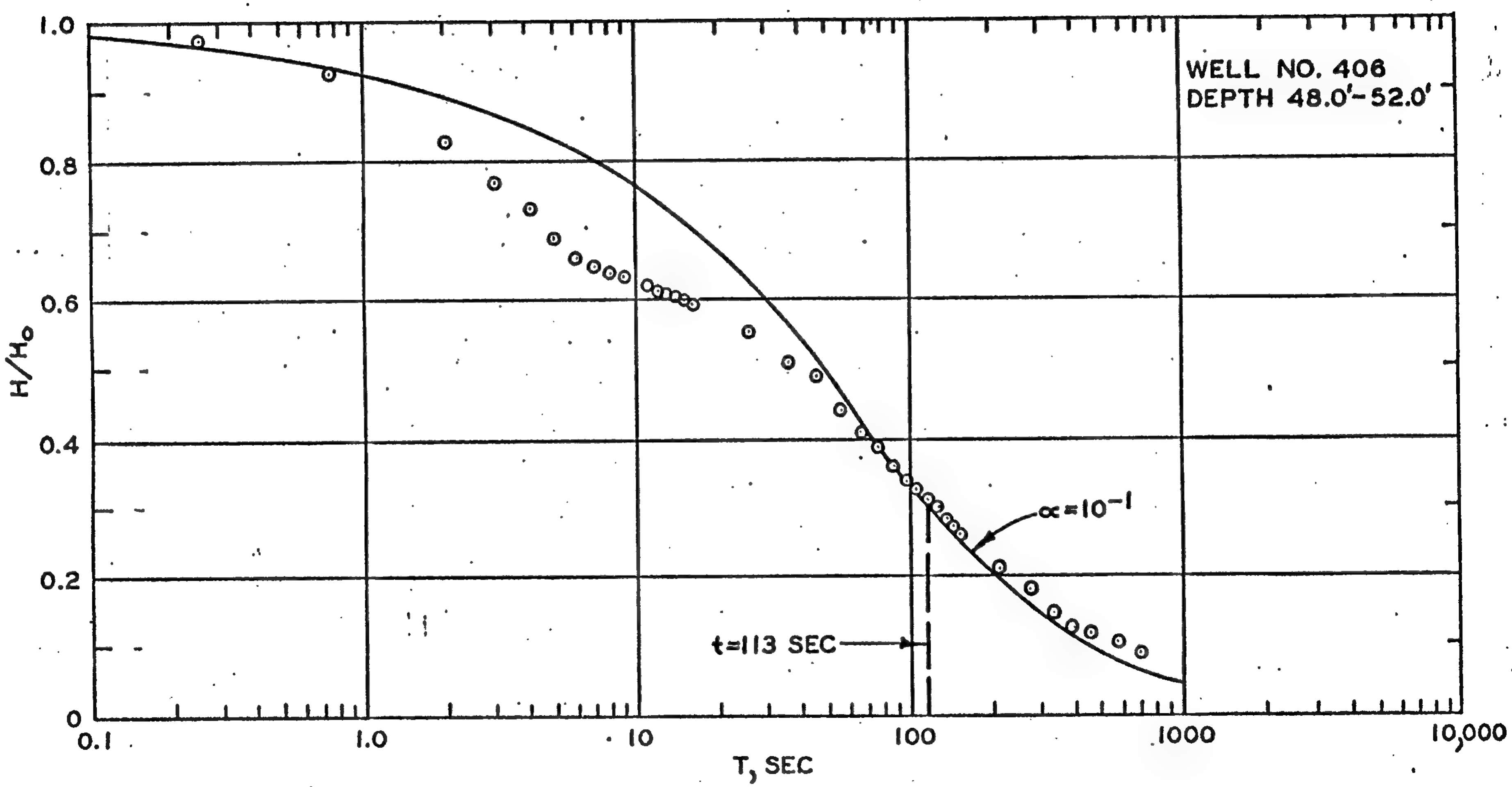
Field Permeability Test Data
with Type Curve

WELL #402
DEPTH 40.7-44.7



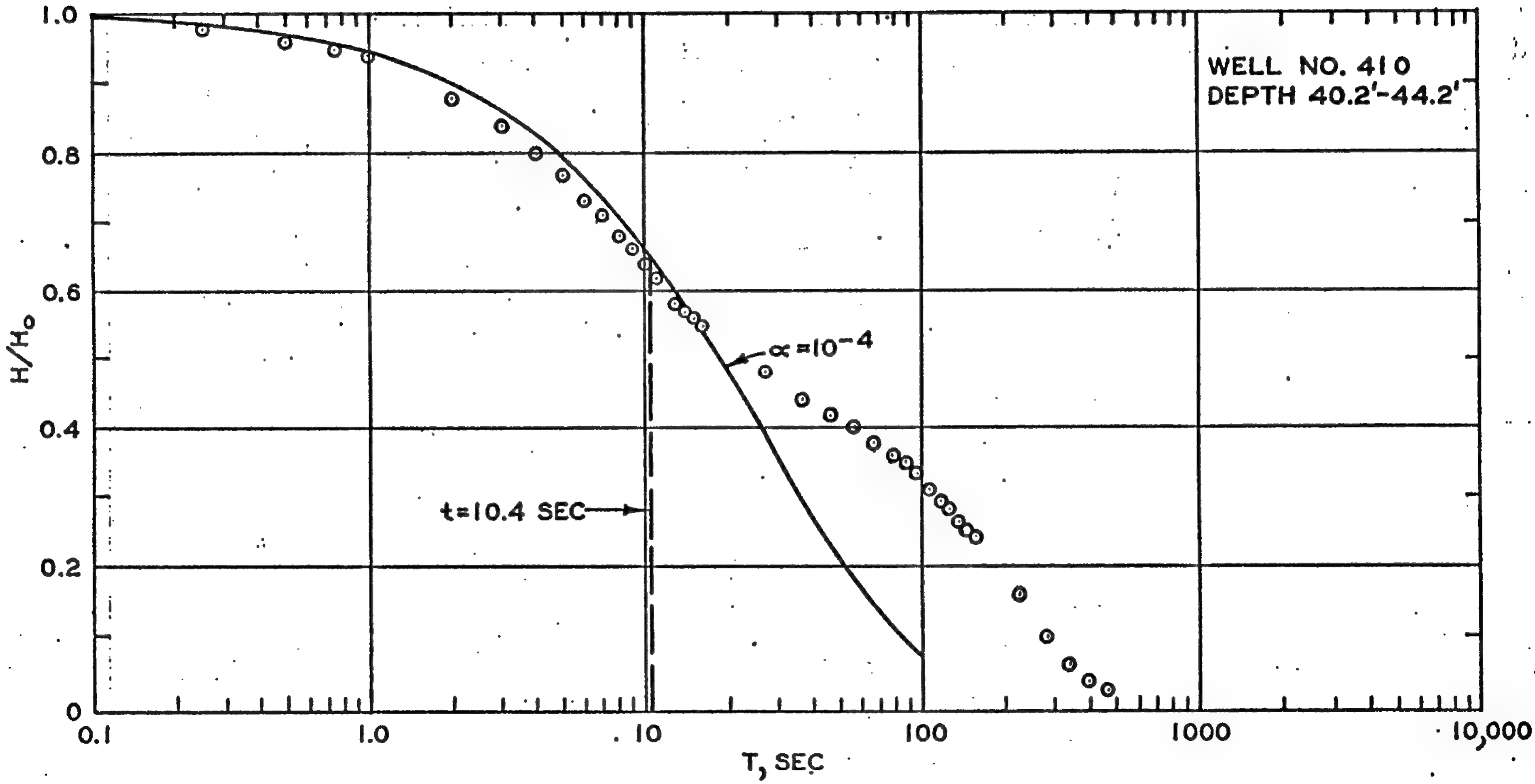
Field Permeability Test Data
with Type Curve

Well # 406
DEPTH 48.0-52.0

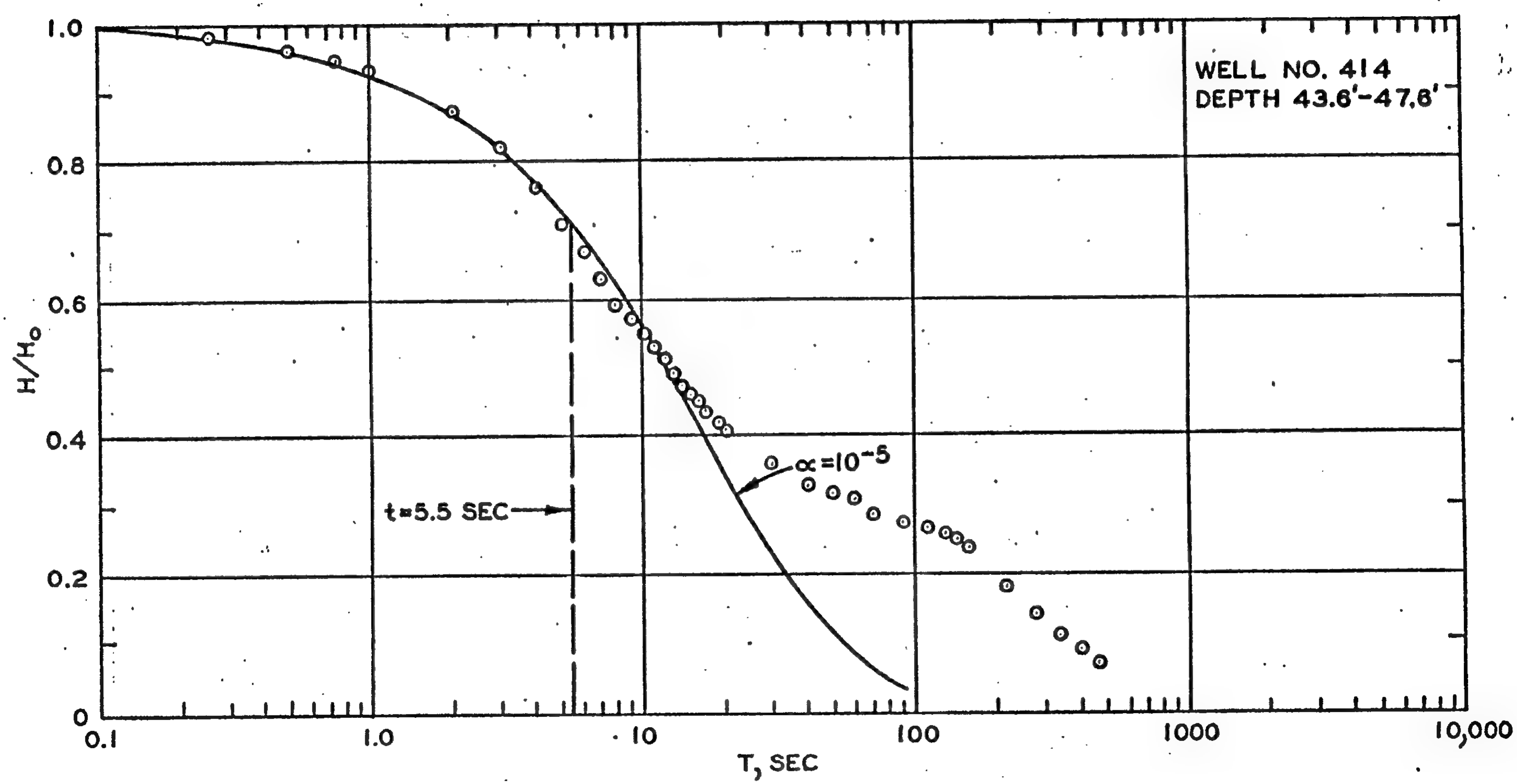


Field Permeability Test Data
with Type Curve

WELL #410
DEPTH 40.2 - 44.2

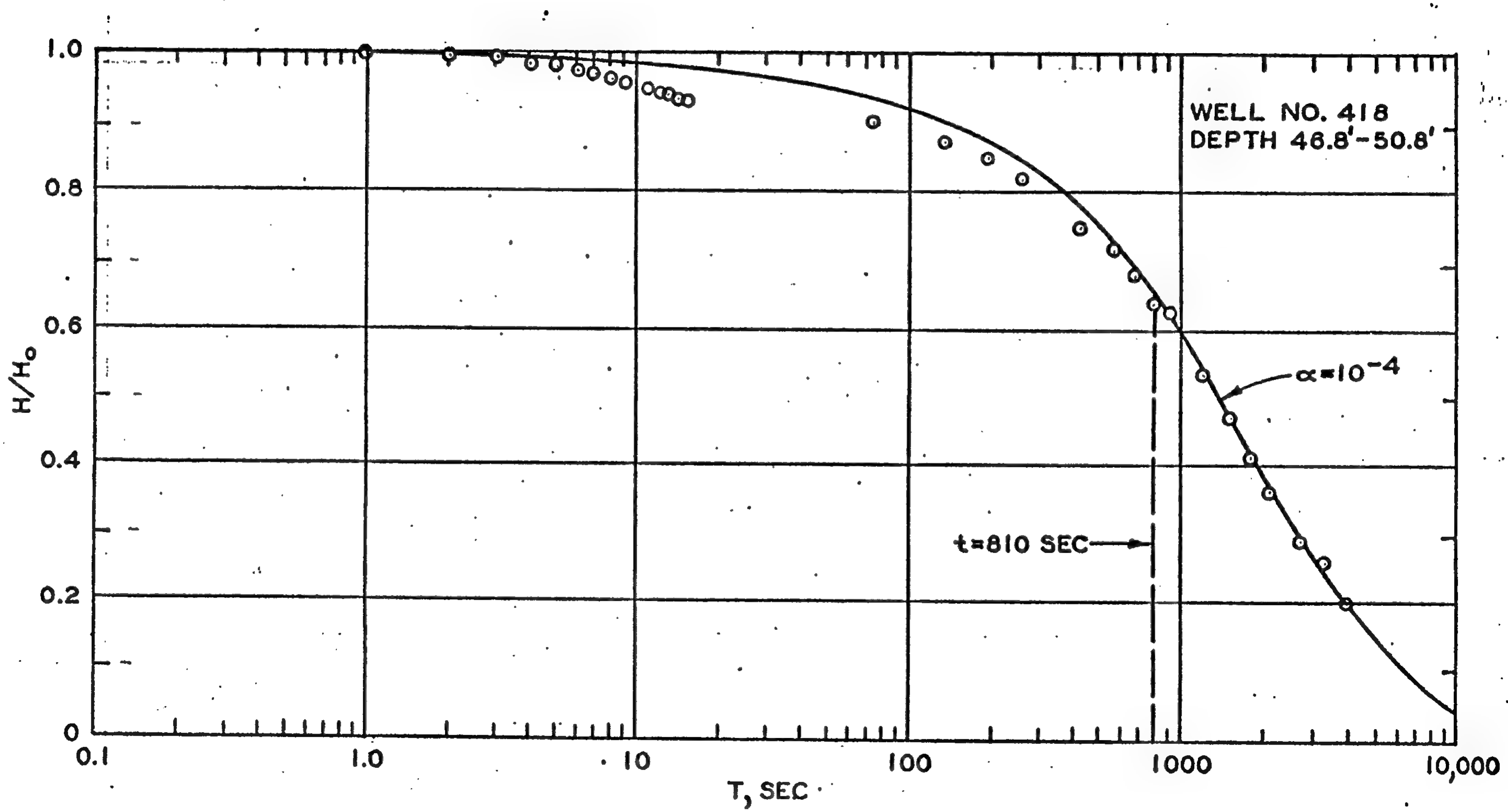


Field Permeability Test Data
with Type Curve



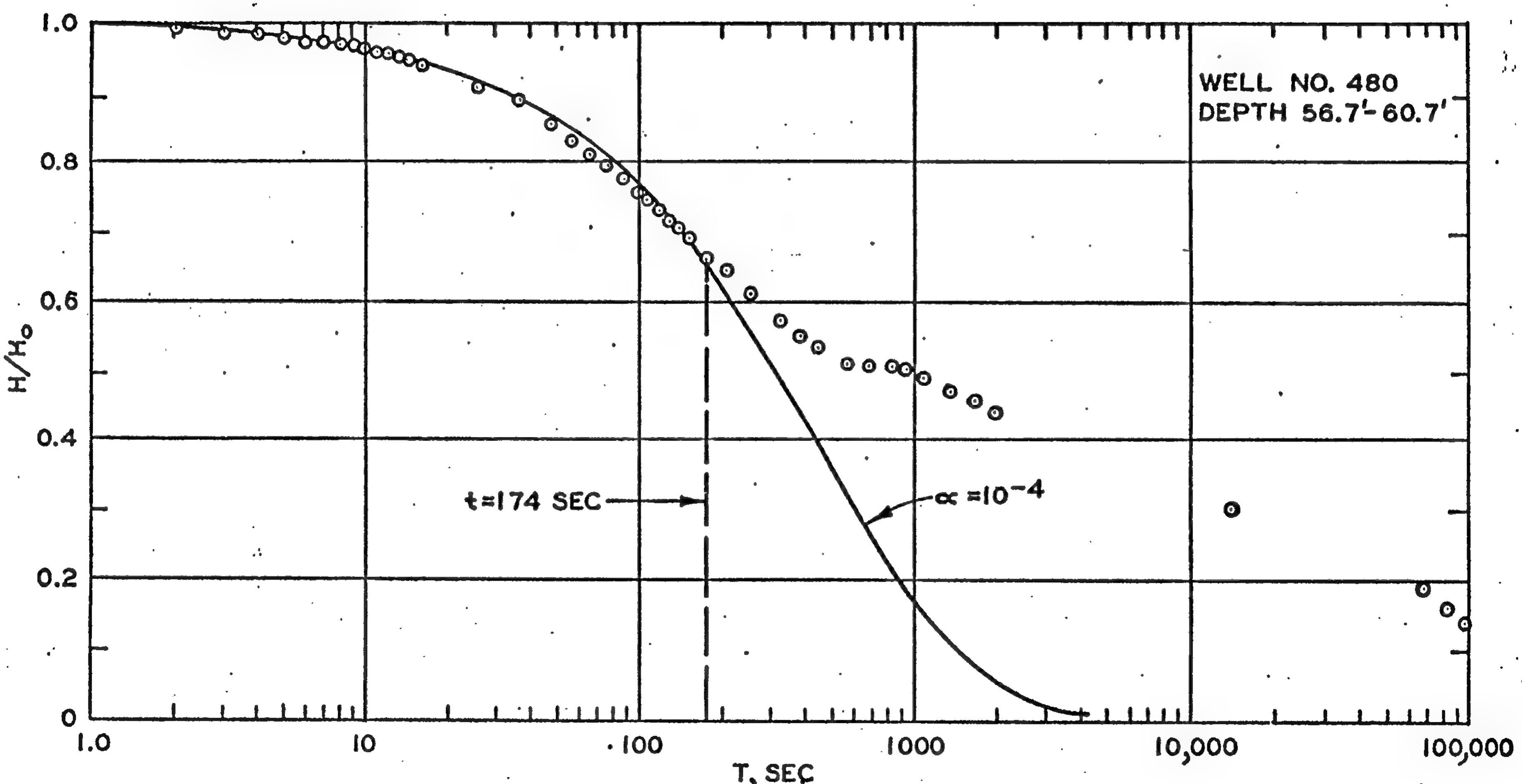
Field Permeability Test Data
with Type Curve

WELL # 418
DEPTH 46.8-50.8



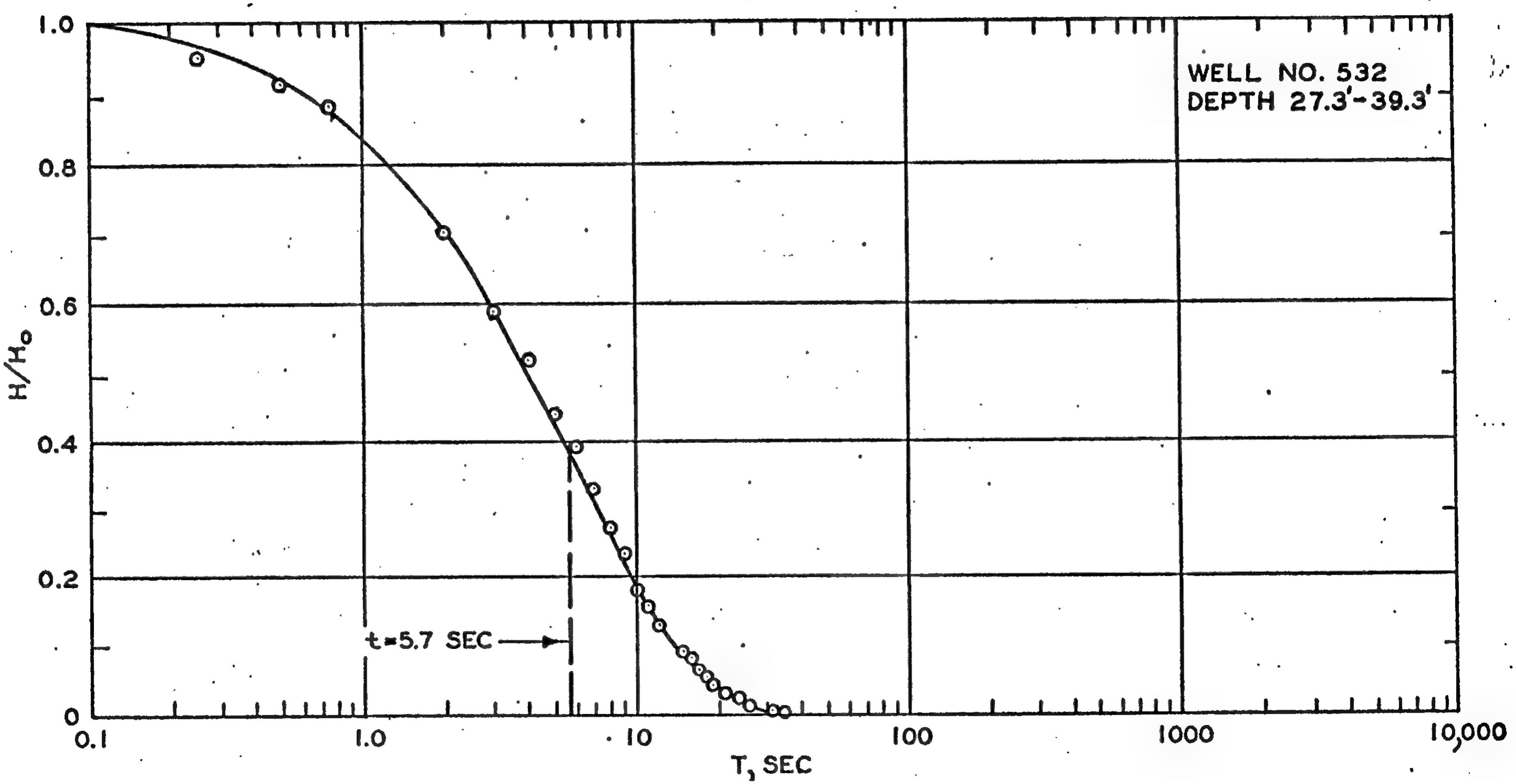
Field Permeability Test Data
with Type Curve

RMA ...
WELL 480
DEPTH 56.7-60.7



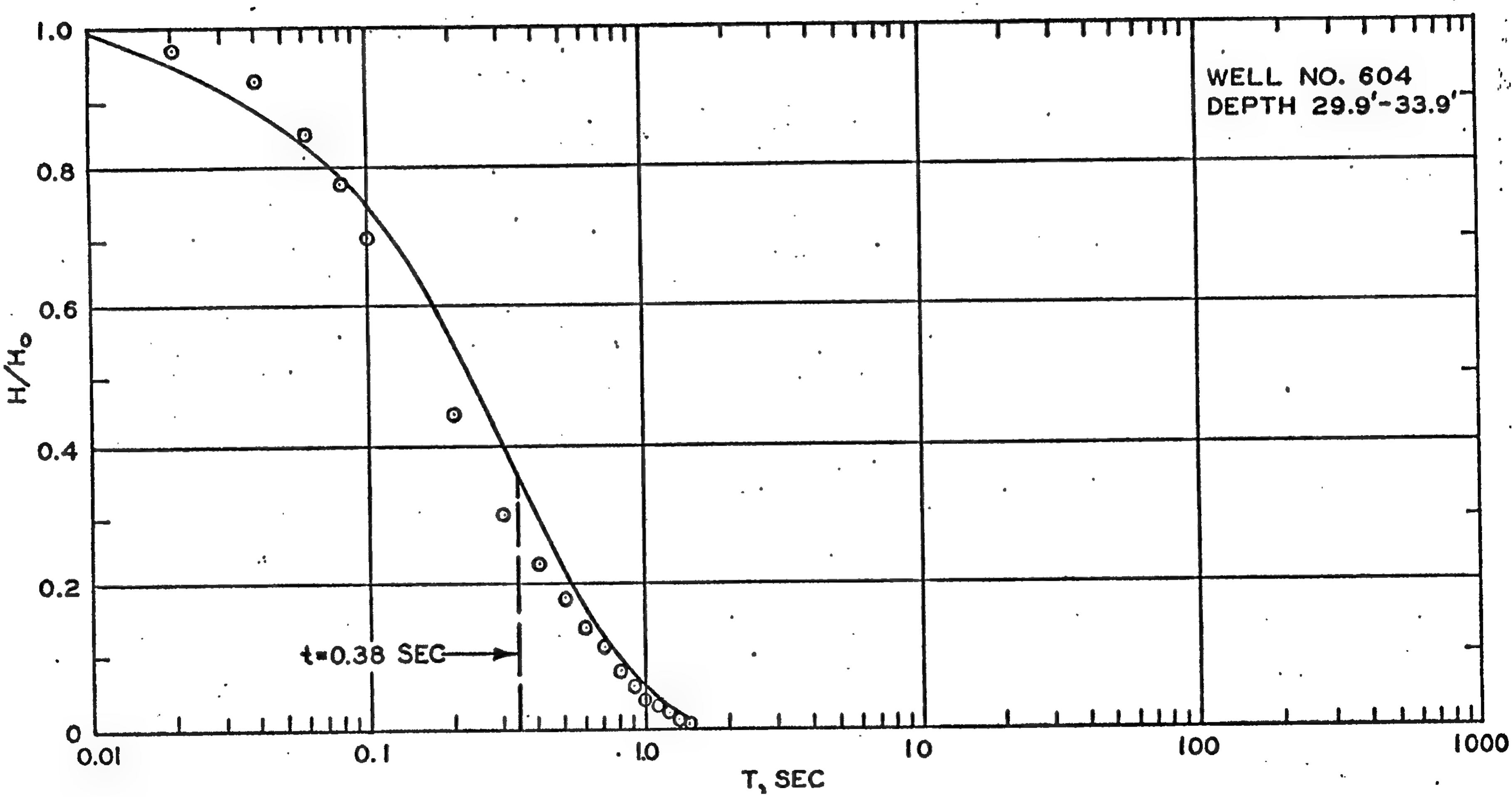
Field Permeability Test Data
with Type Curve

Well 532
Depth 27.3-39.3
unconfined



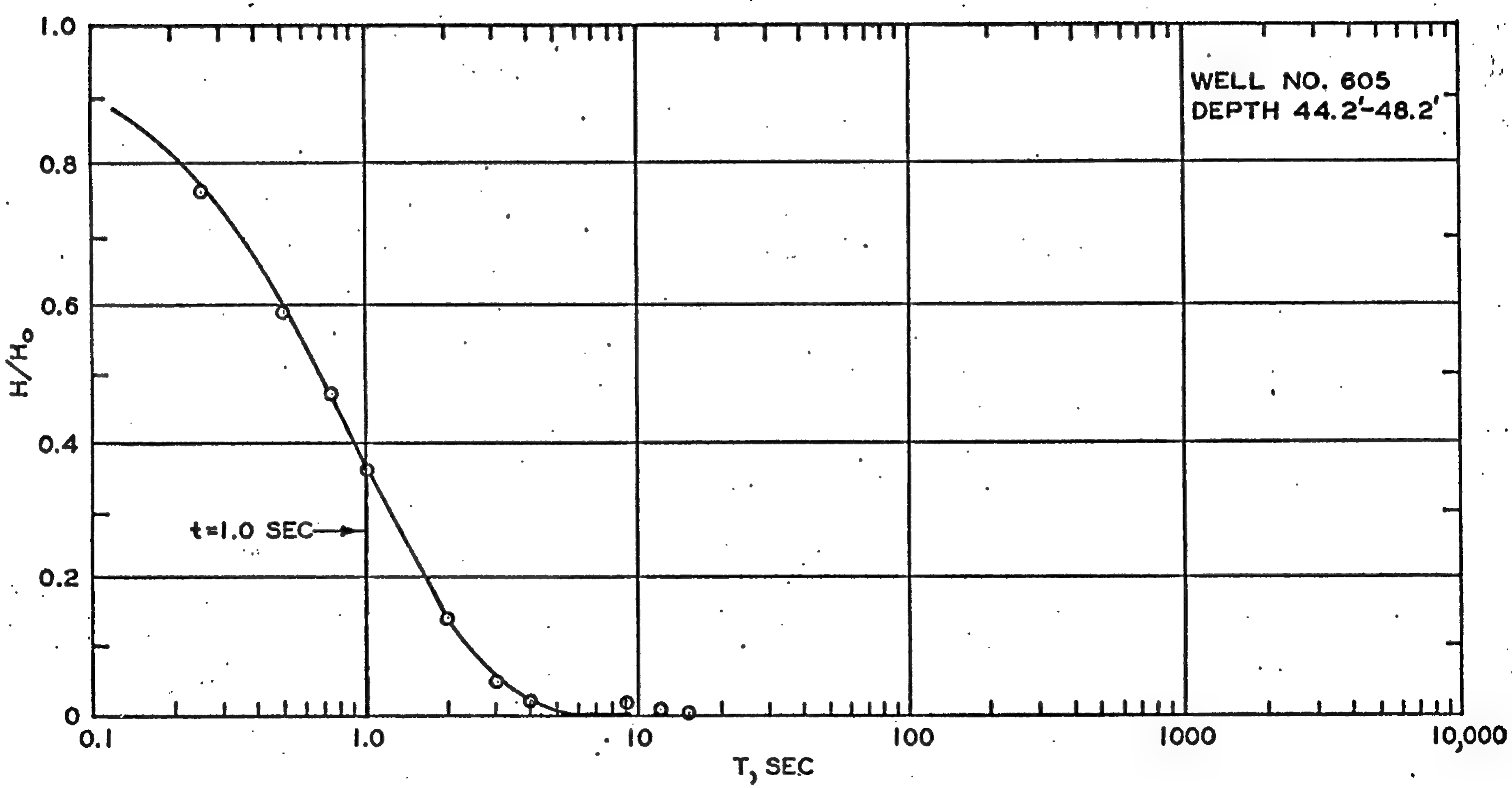
Field Permeability Test Data
with Type Curve

RMA SLUG TEST
WELL 604
DEPTH 29.9-33.9
(unconfined)



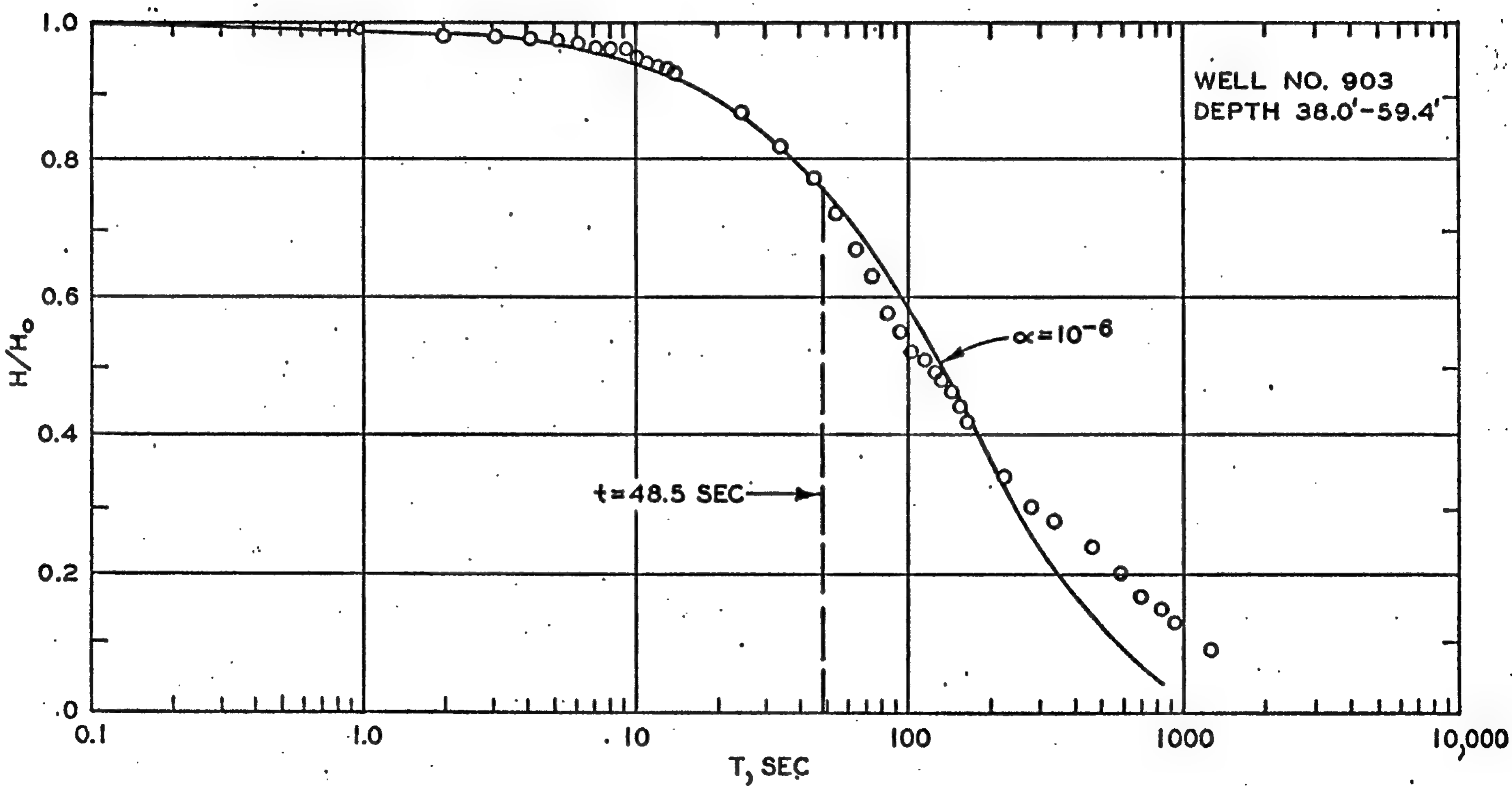
Field Permeability Test Data
with Type Curve

RMA Slug Test
Well 605
Depth 44.2 - 48.2



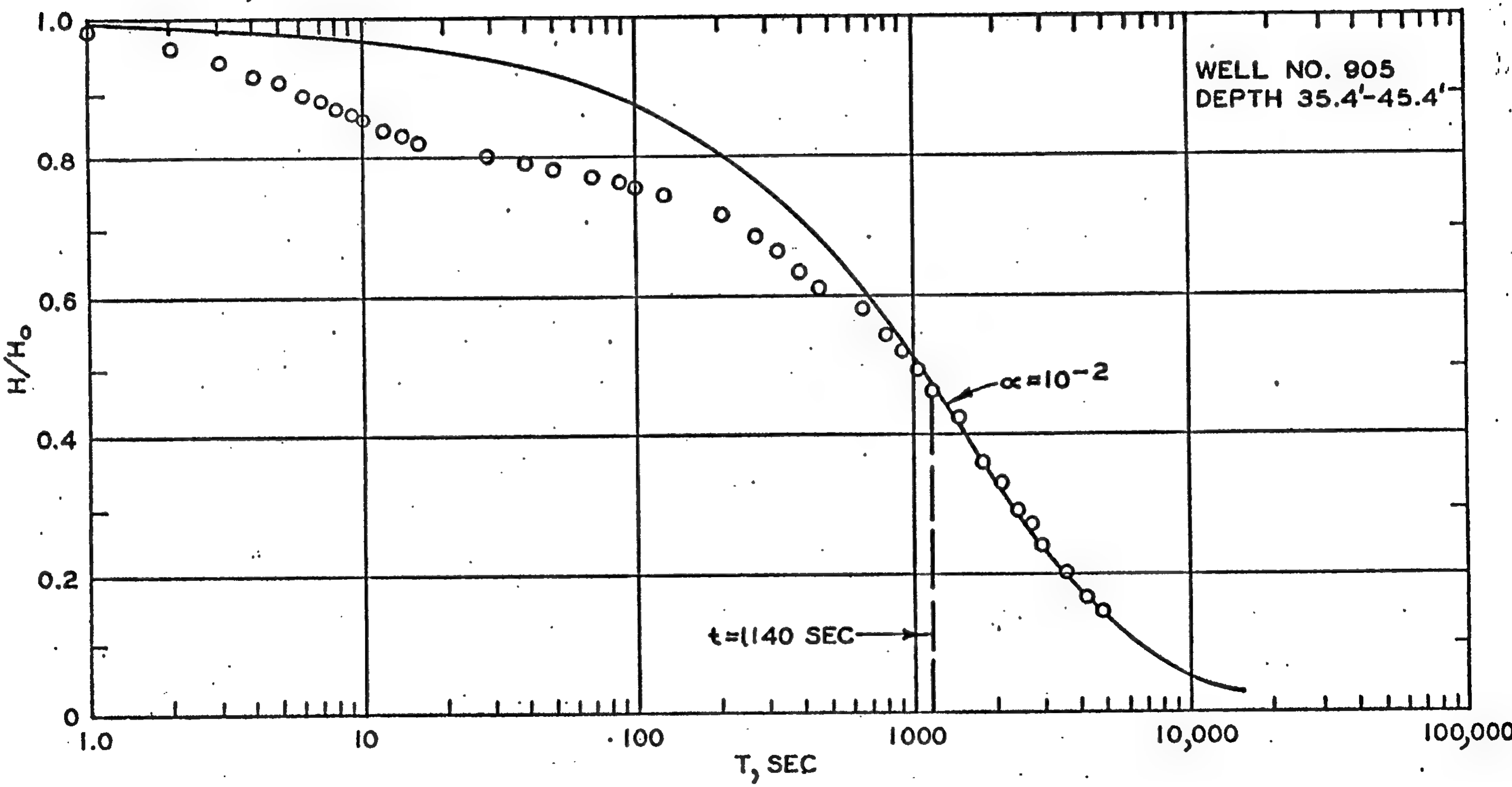
Field Permeability Test Data
with Type Curve

Well 903
Depth 38.0-59.4



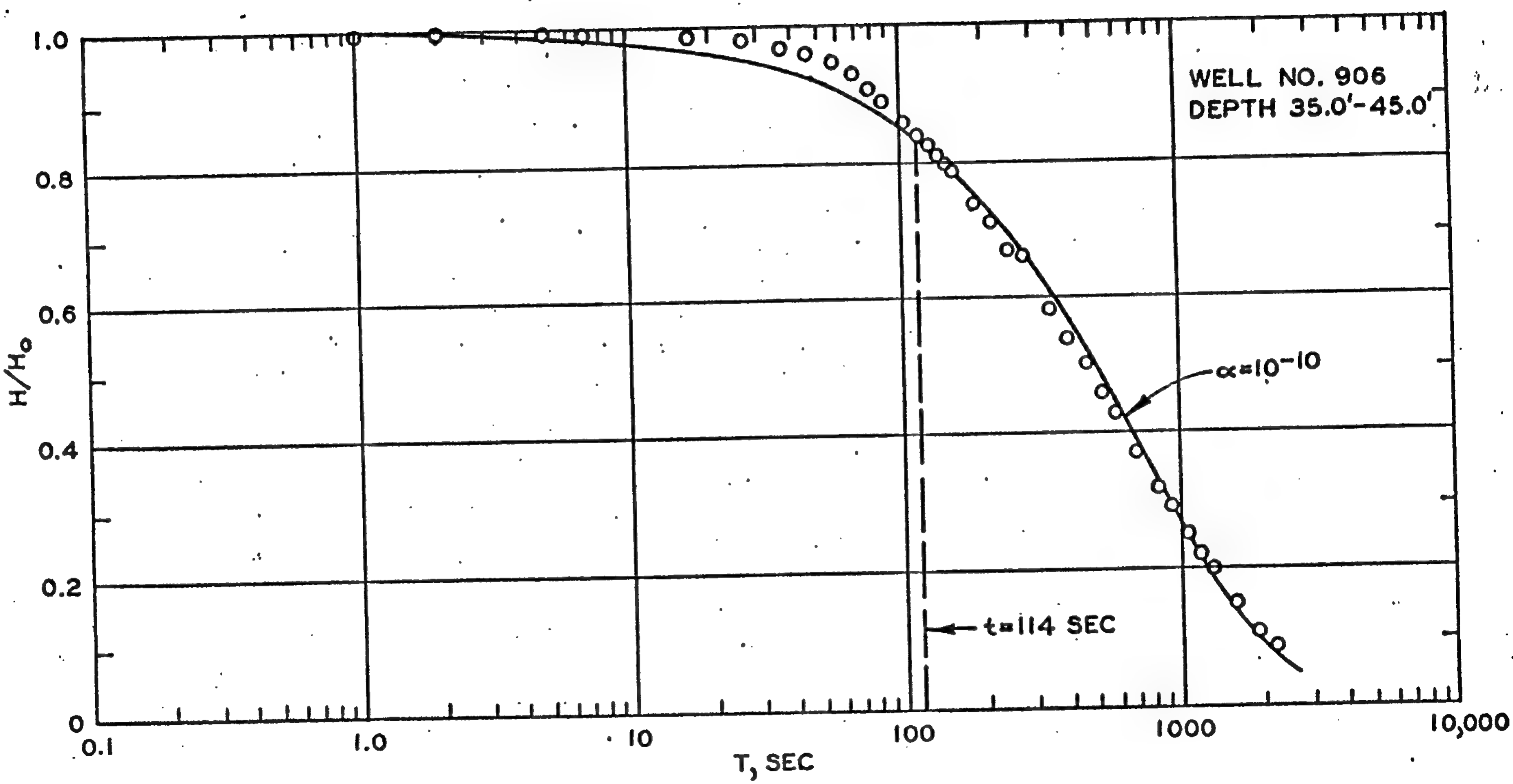
Field Permeability Test Data
with Type Curve

WELL 905
DEPTH 35.4 - 45.4

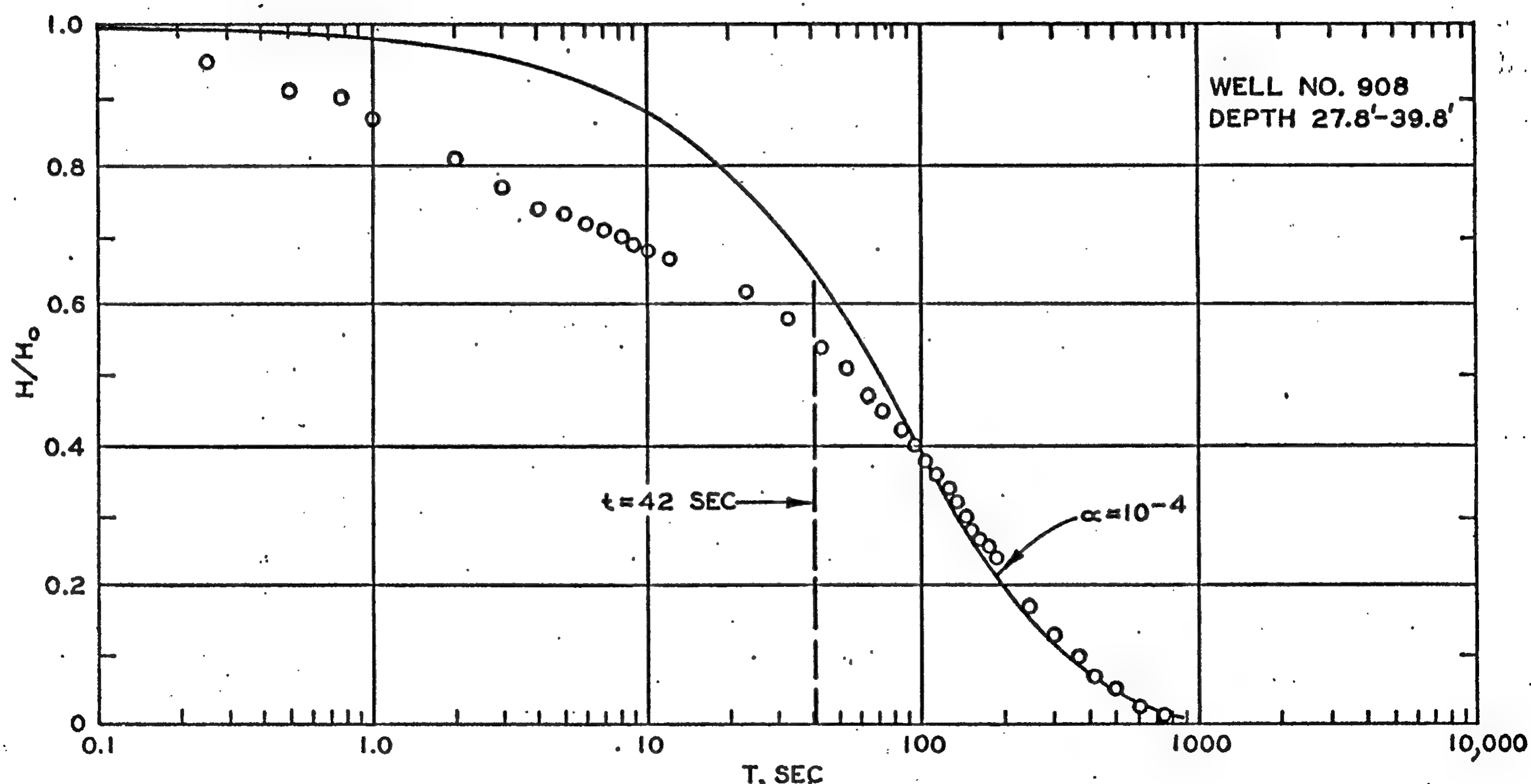


Field Permeability Test Data
with Type Curve

RHA FHT
WELL 906
DEPTH 35.0-45.0

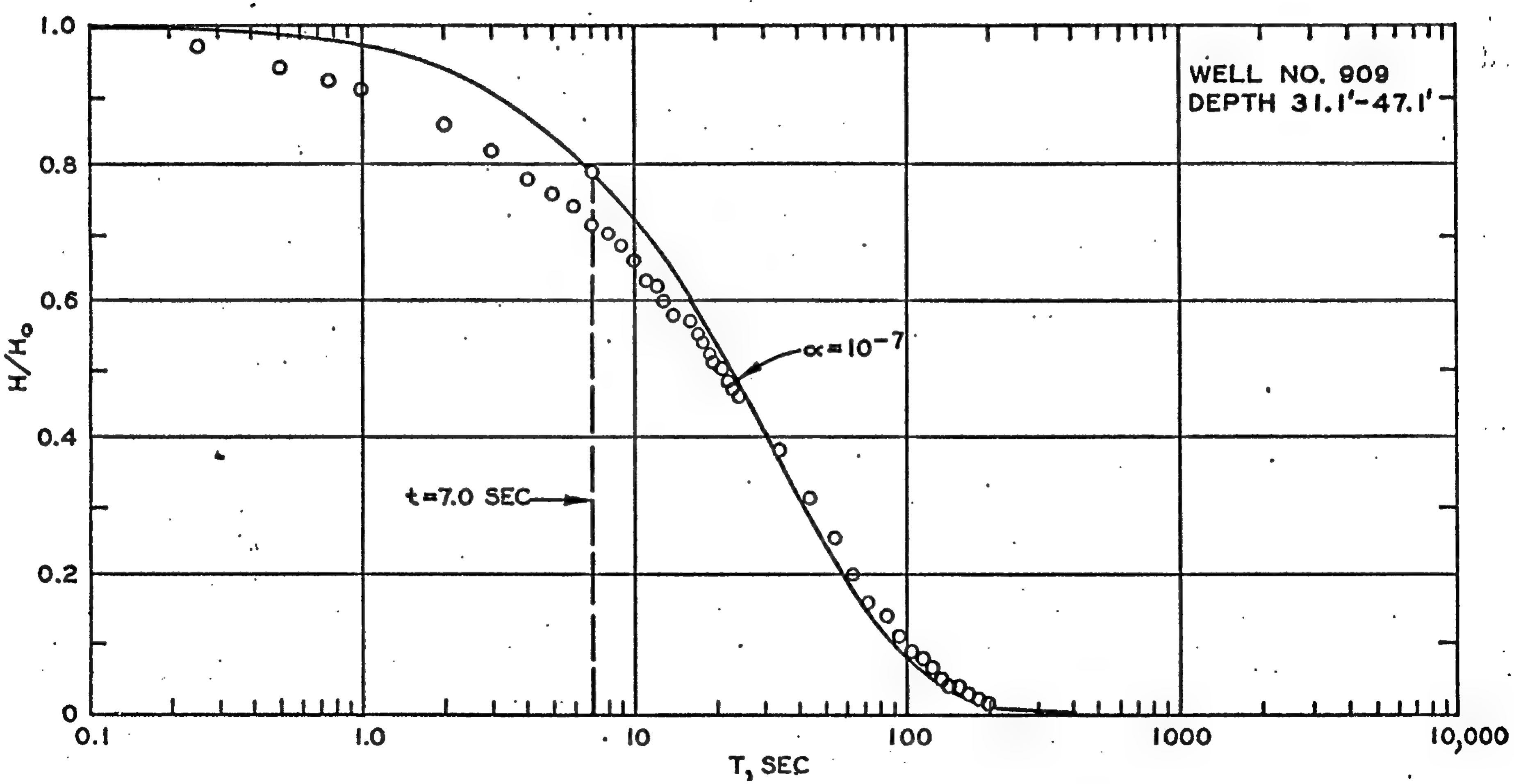


Field Permeability Test Data
with Type Curve



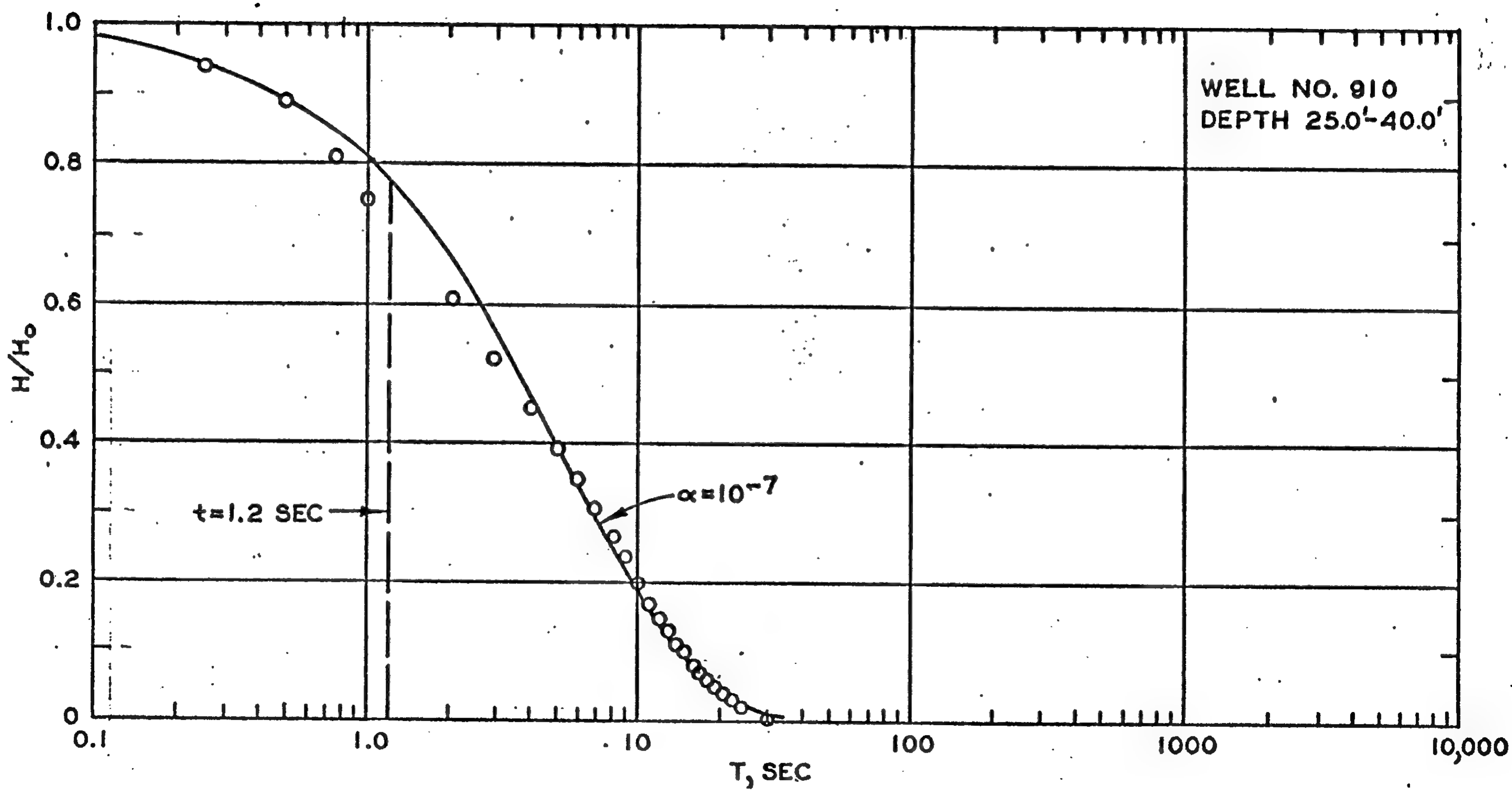
Field Permeability Test Data
with Type Curve

Well 909
Depth 31.1 – 47.1



Field Permeability Test Data
with Type Curve

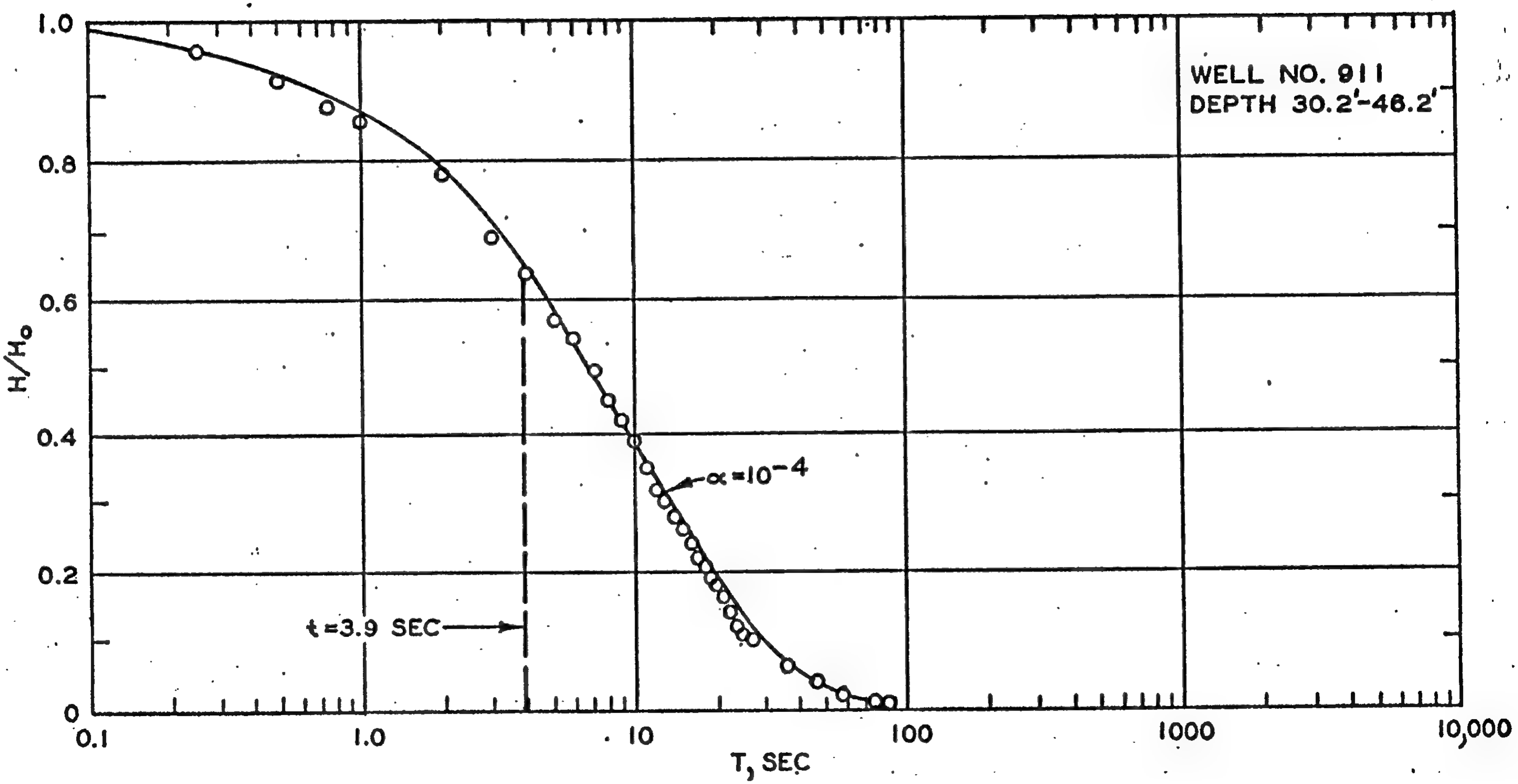
Well 910
Depth 25.0 - 40.0



Field Permeability Test Data
with Type Curve

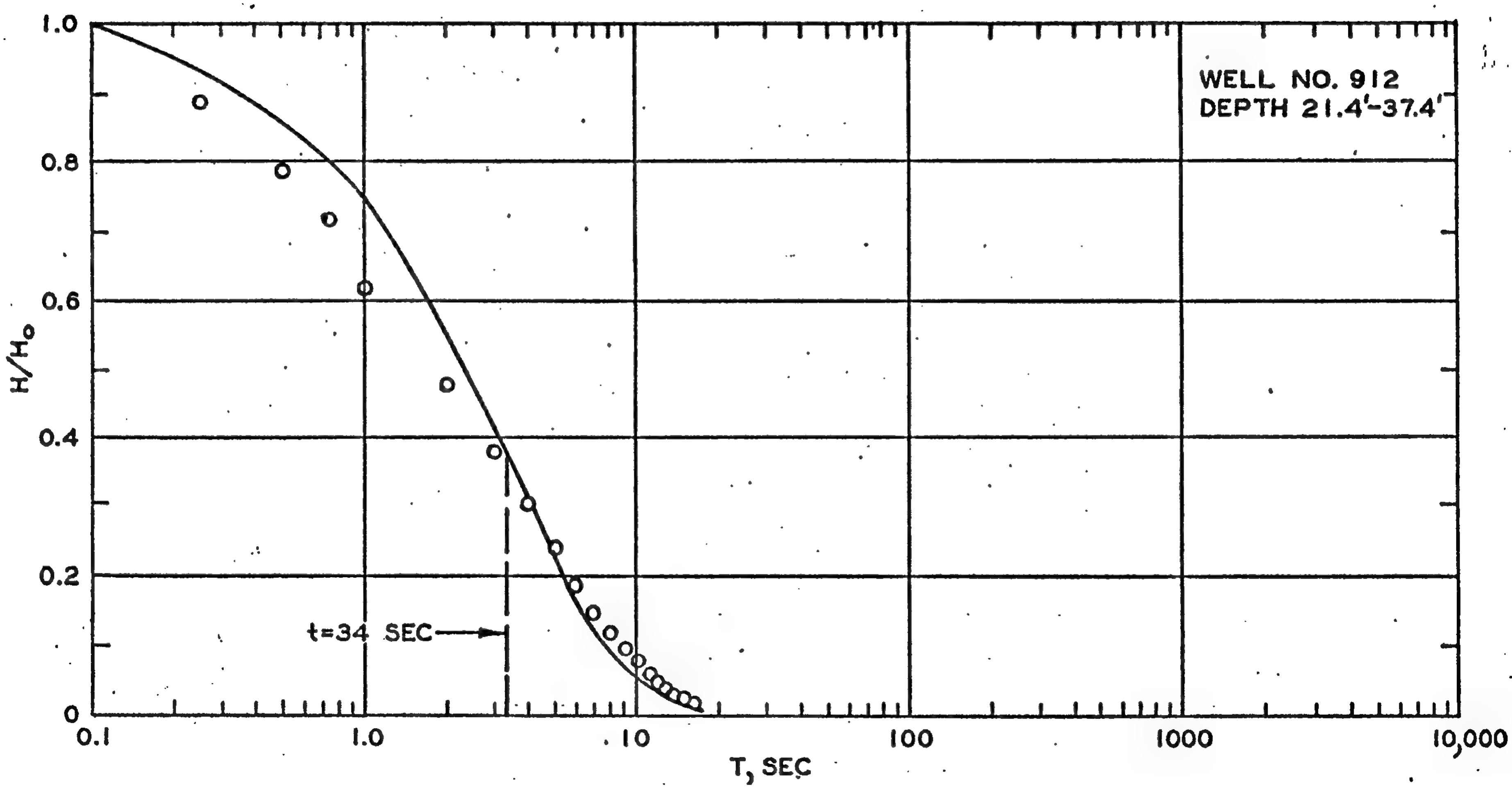
Plate B25

Depth 30.2'-46.2'

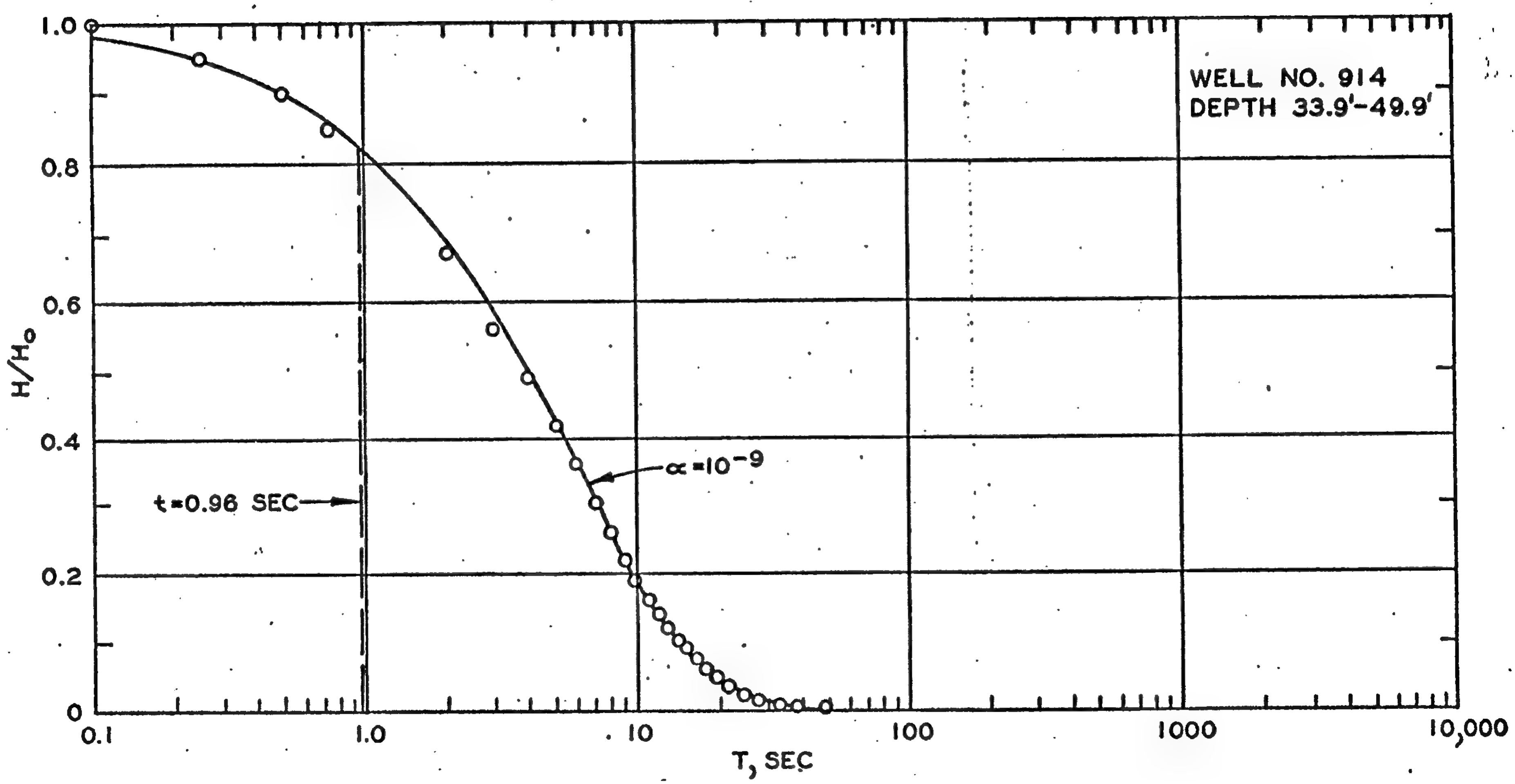


Field Permeability Test Data
with Type Curve

Well 912
Depth 21.4 - 37.4
unconfined

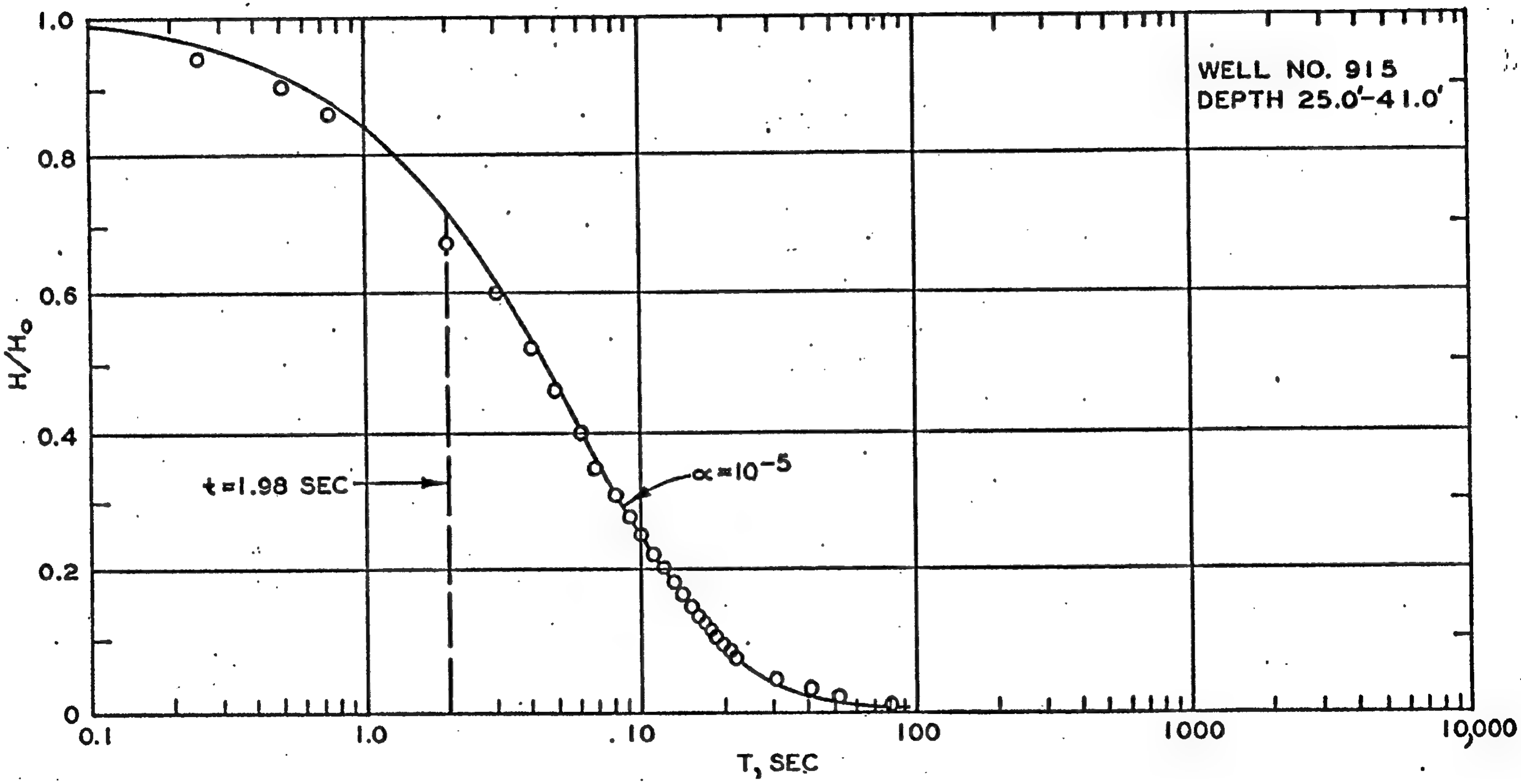


Field Permeability Test Data
with Type Curve



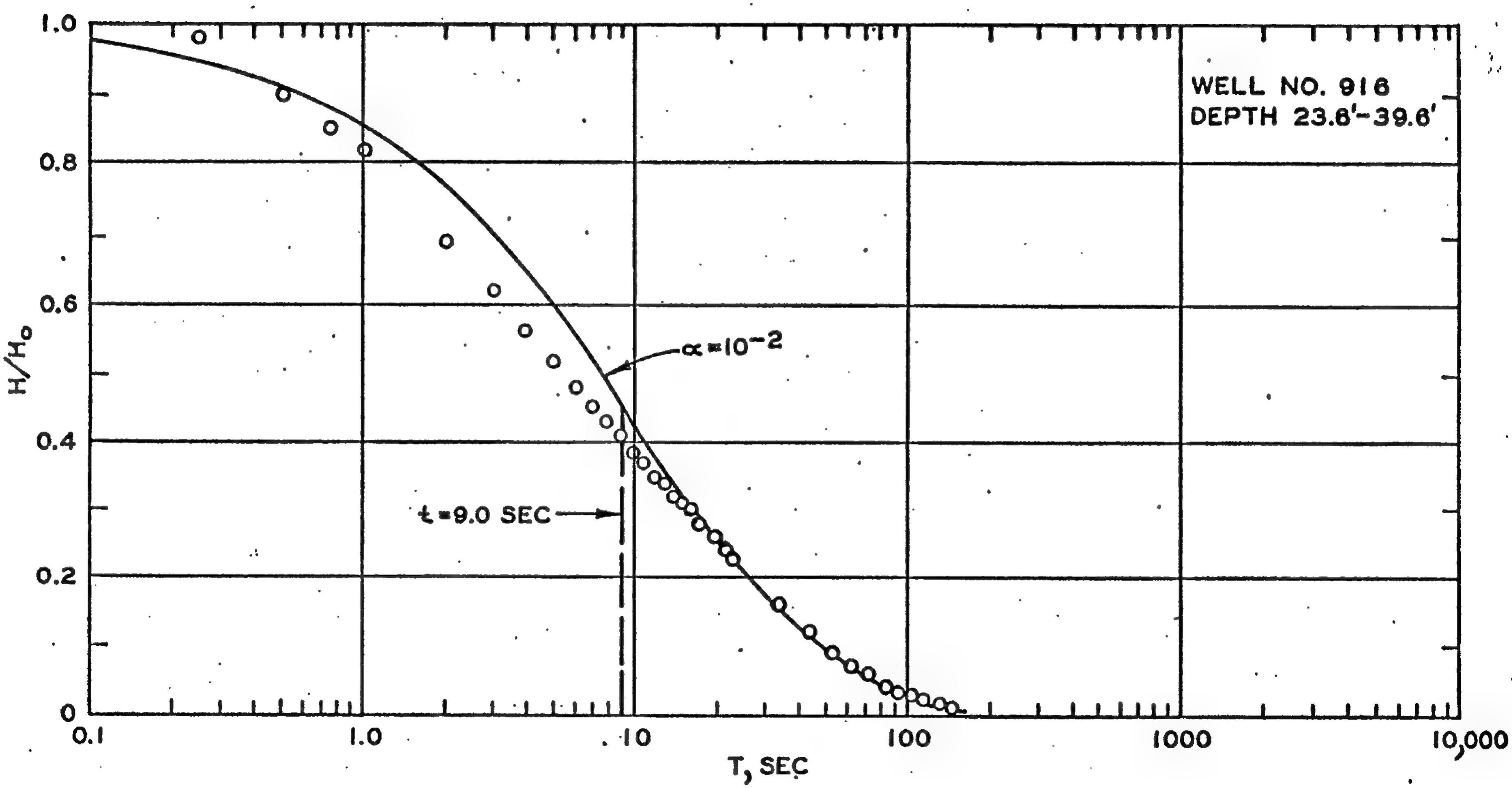
Field Permeability Test Data
with Type Curve

Depth 25.0

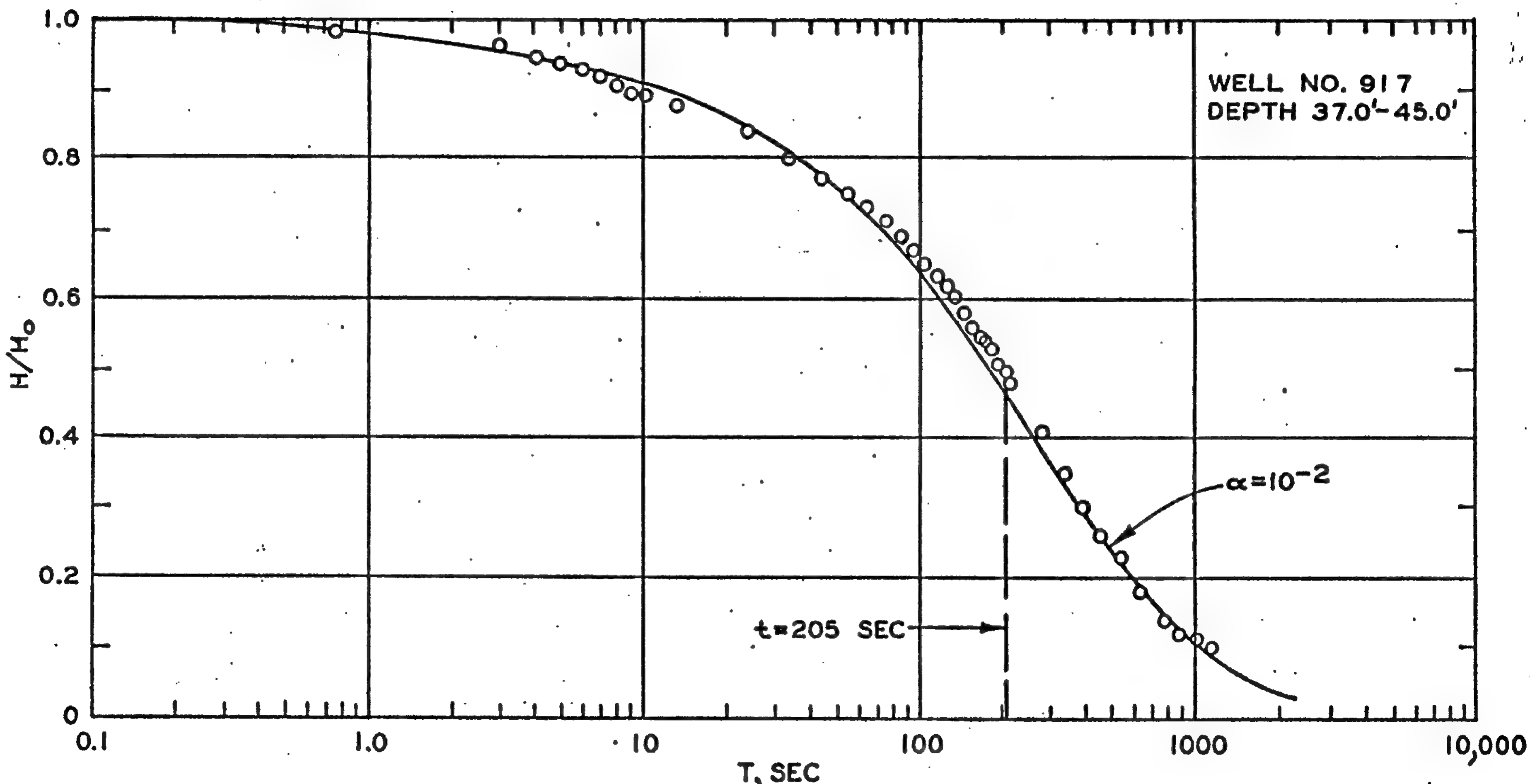


Field Permeability Test Data
with Type Curve

Depth 23.6'-39.6

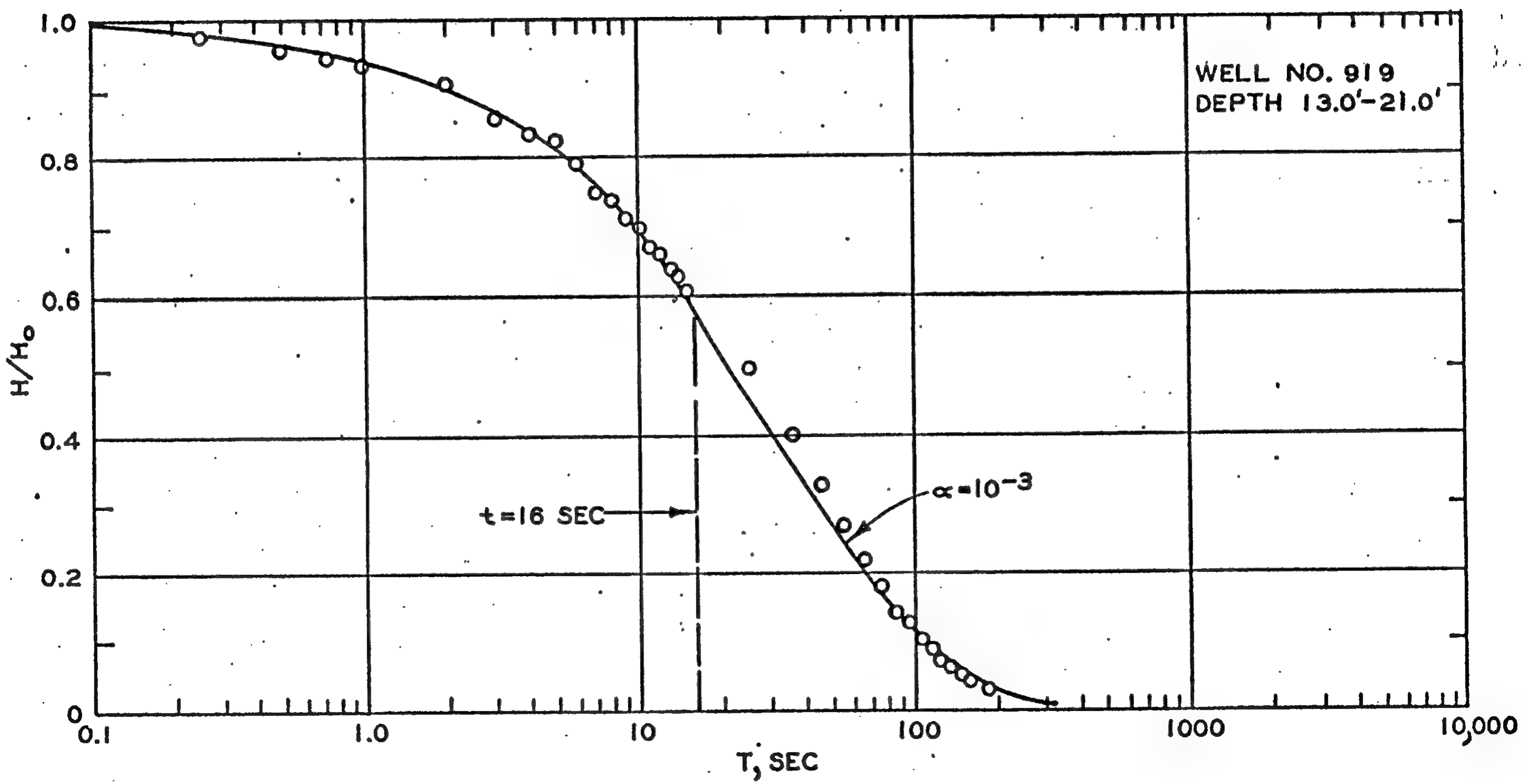


Field Permeability Test Data
with Type Curve



Field Permeability Test Data
with Type Curve

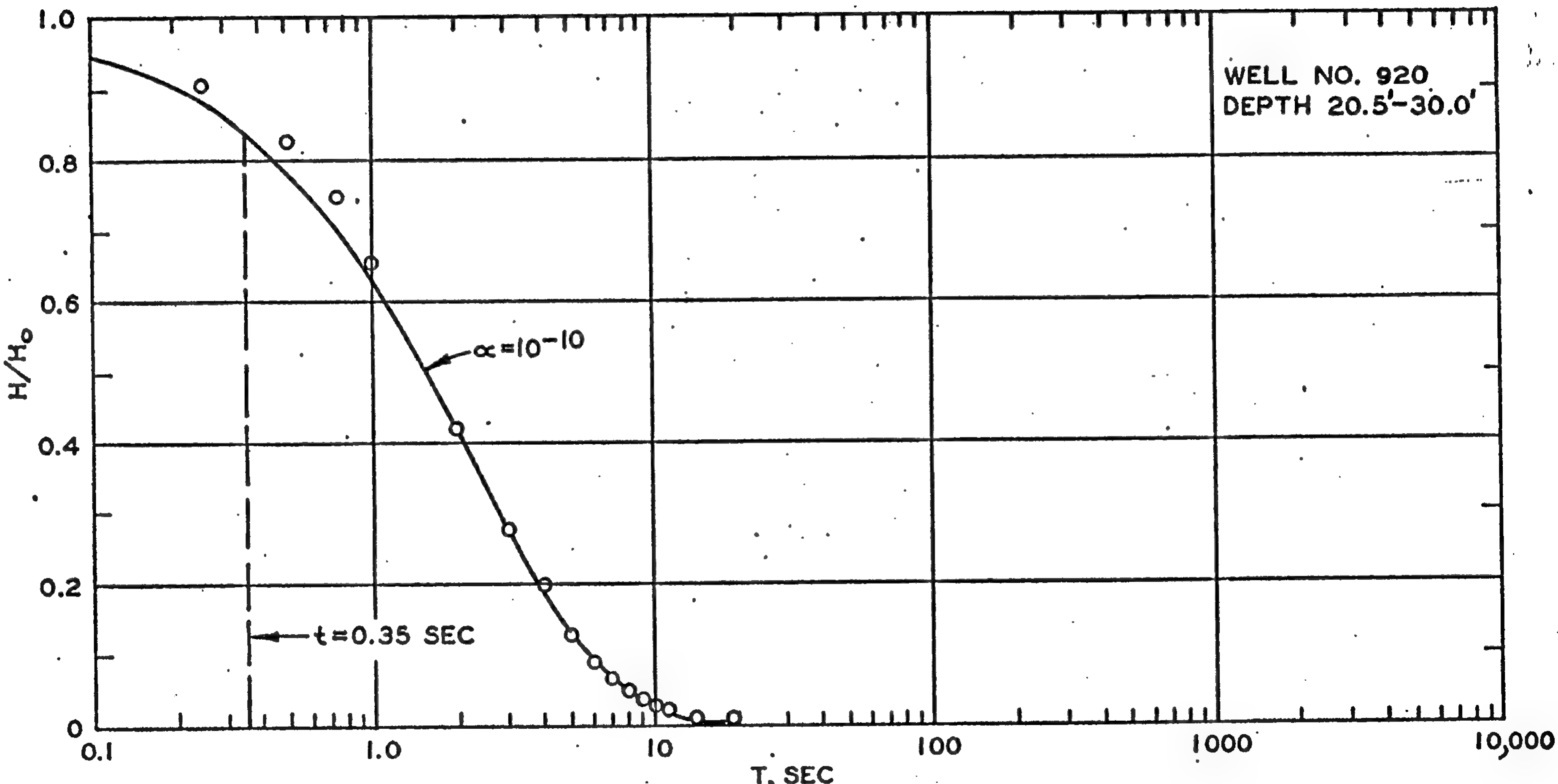
Depth 13.0-21.



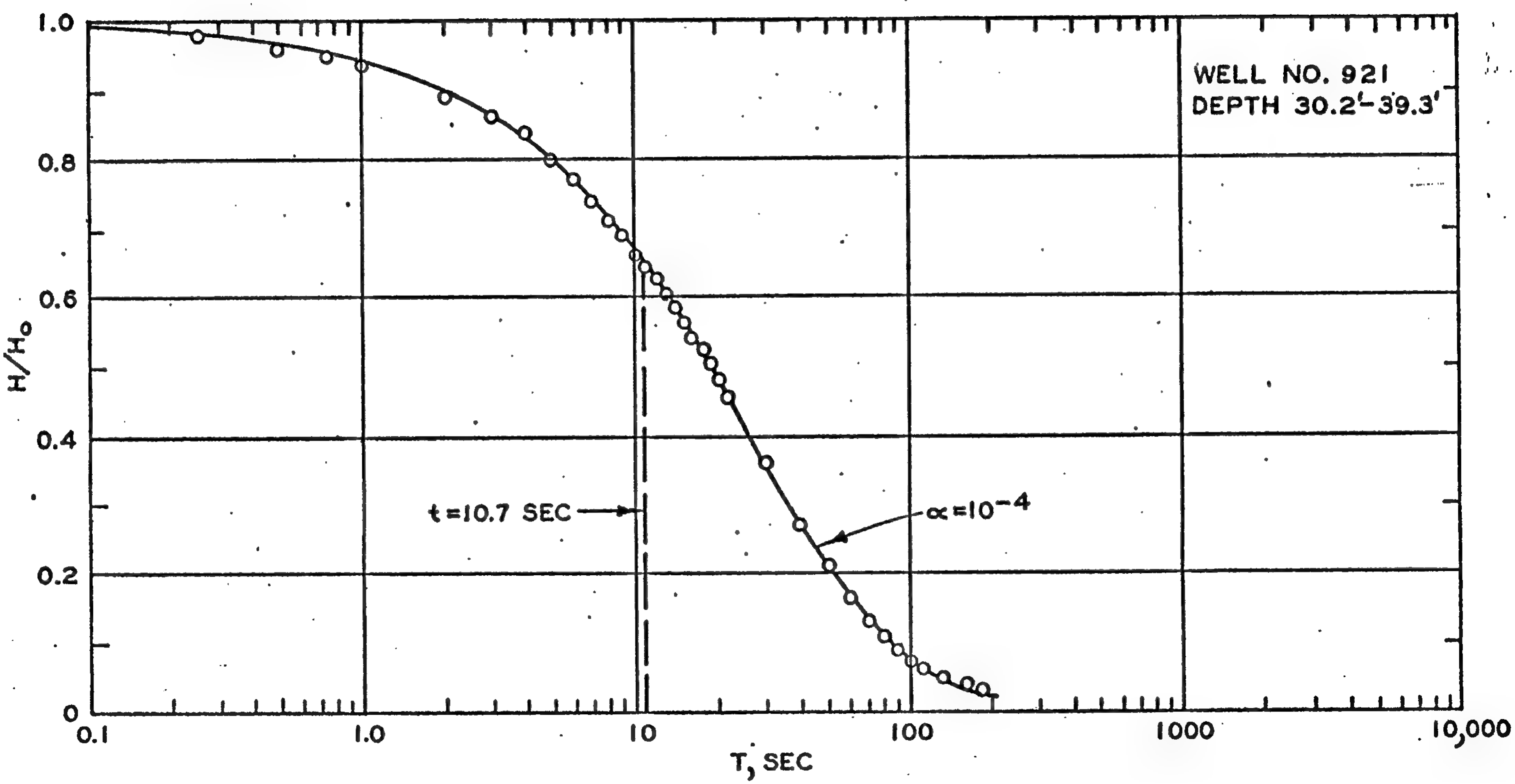
WELL NO. 919
DEPTH 13.0'-21.0'
1.0
0.8
0.6
0.4
0.2
0
H/Ho
0.1
1.0
10
100
1000
10,000
T, SEC
t=16 SEC
α=10^-3

depth 20.5-30.0

unconfined

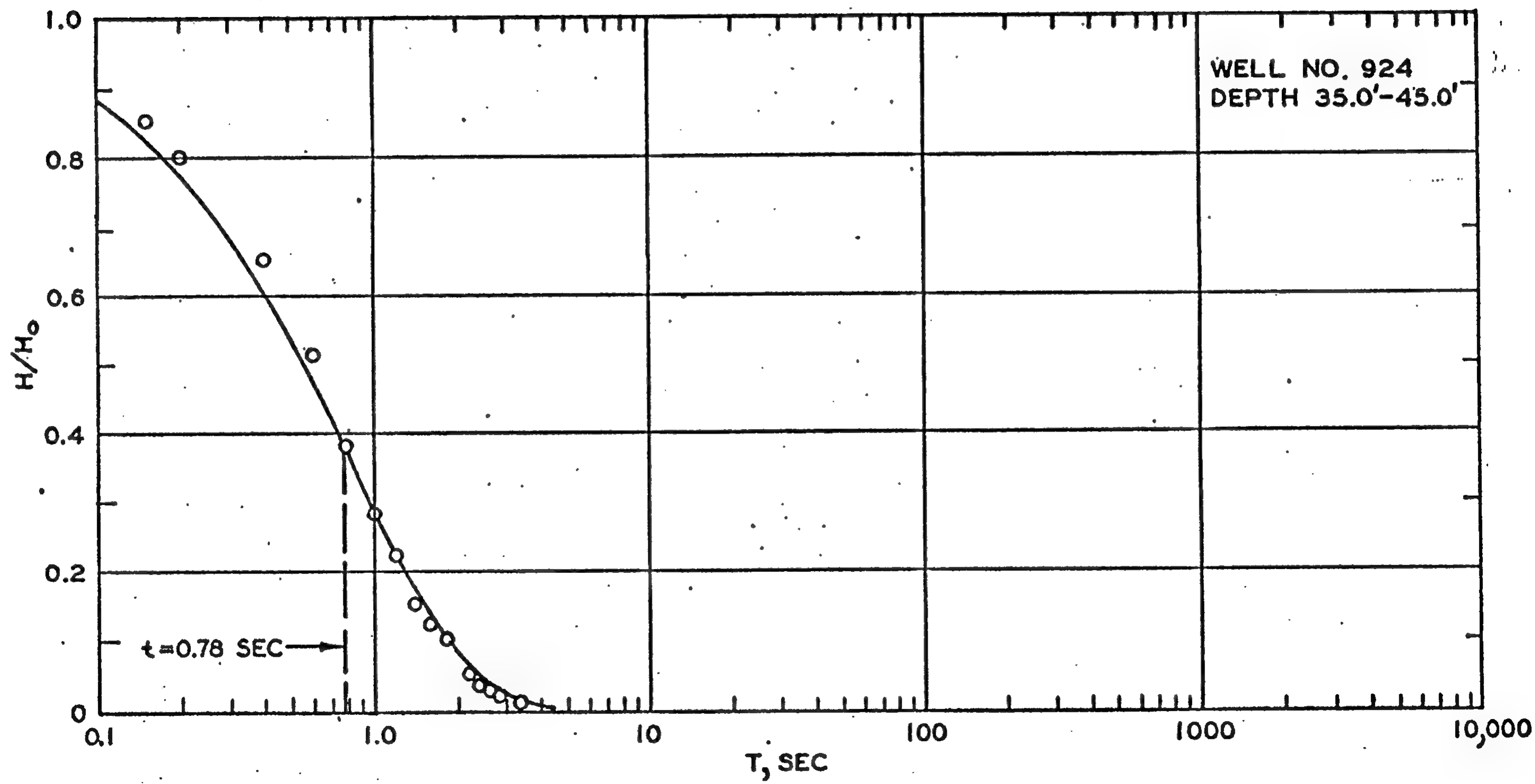


Field Permeability Test Data
with Type Curve



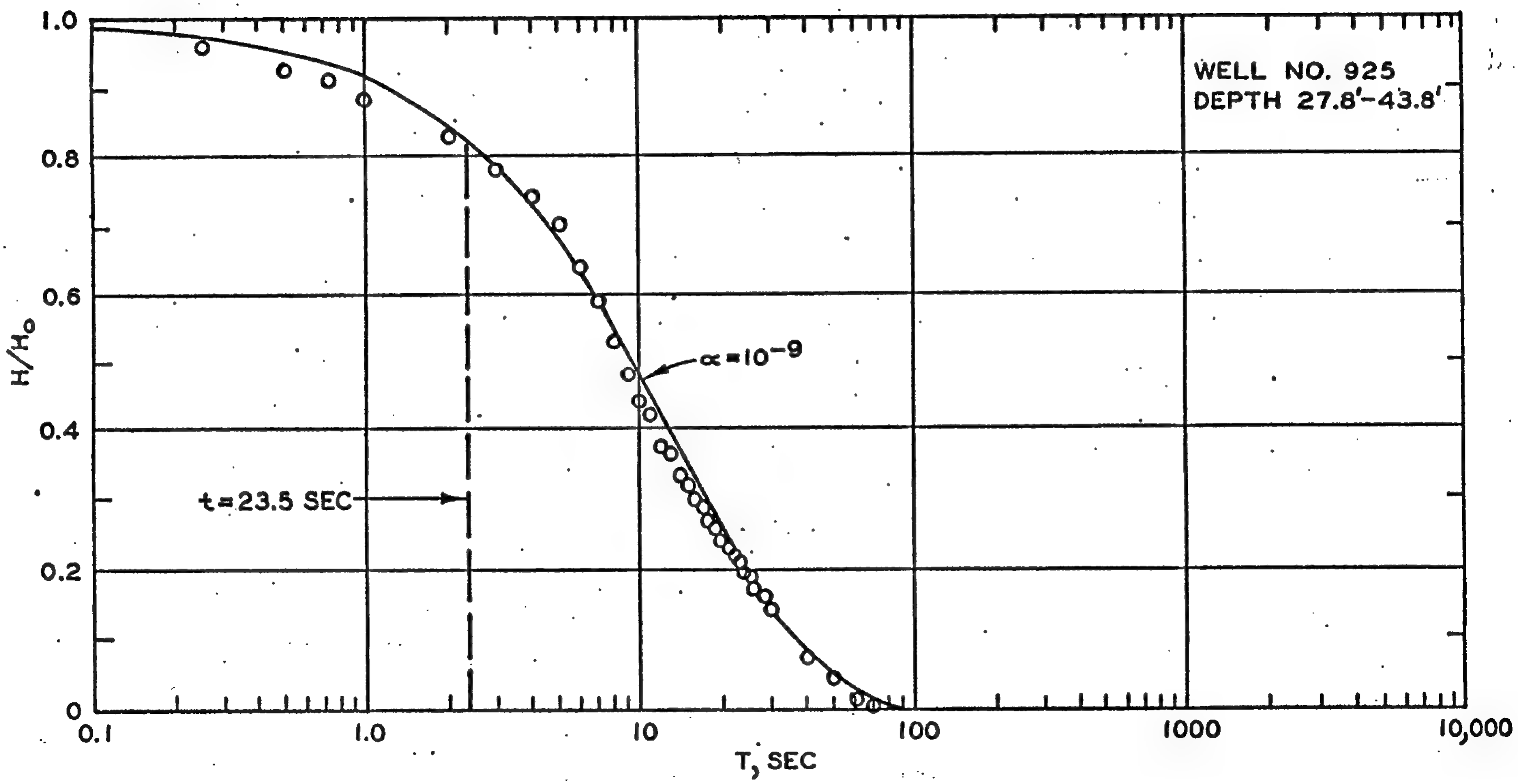
Field Permeability Test Data
with Type Curve

Well 924.
depth 35.0- 45.0
Unconf.



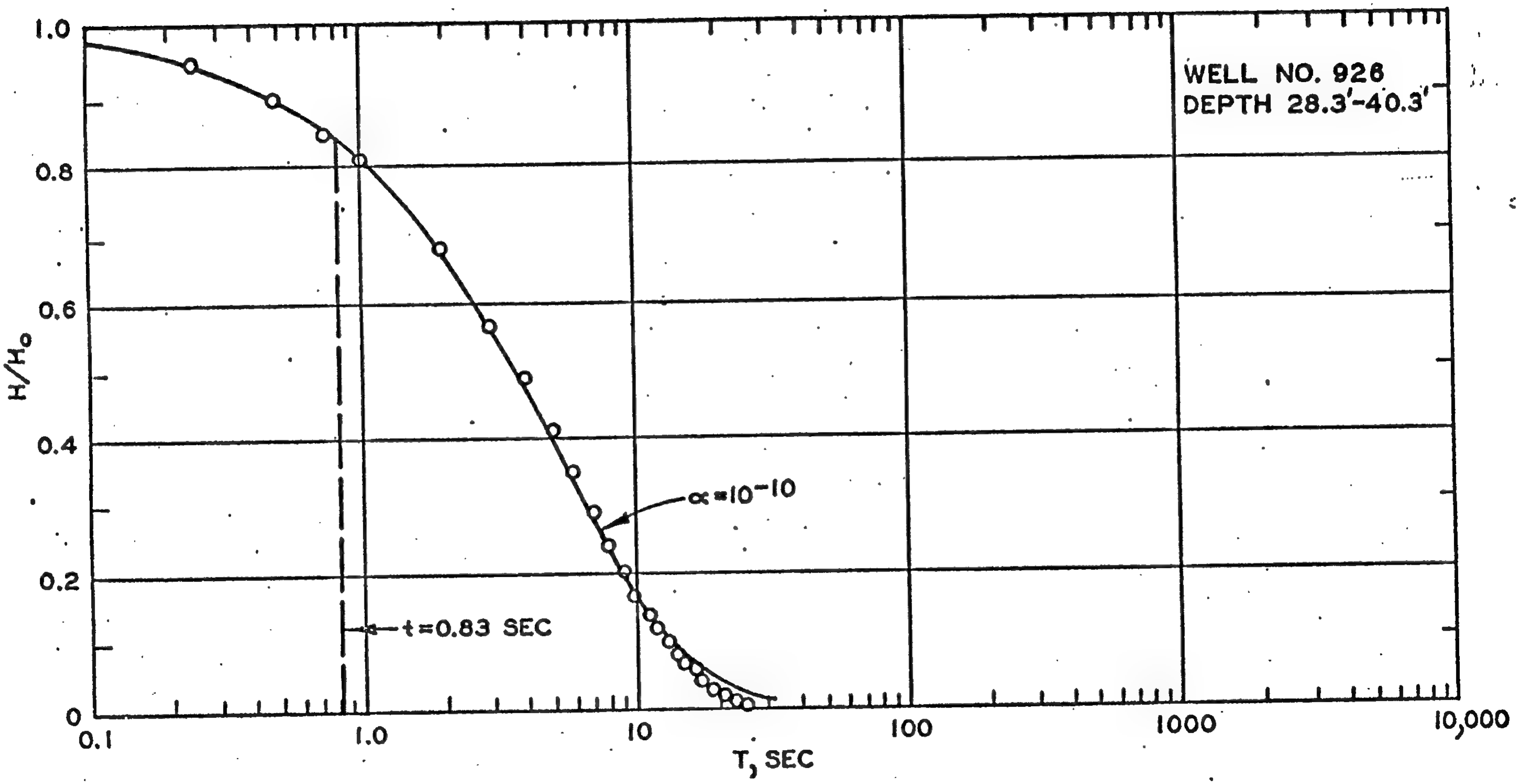
Field Permeability Test Data
with Type Curve

depth 28.8 - 43.8



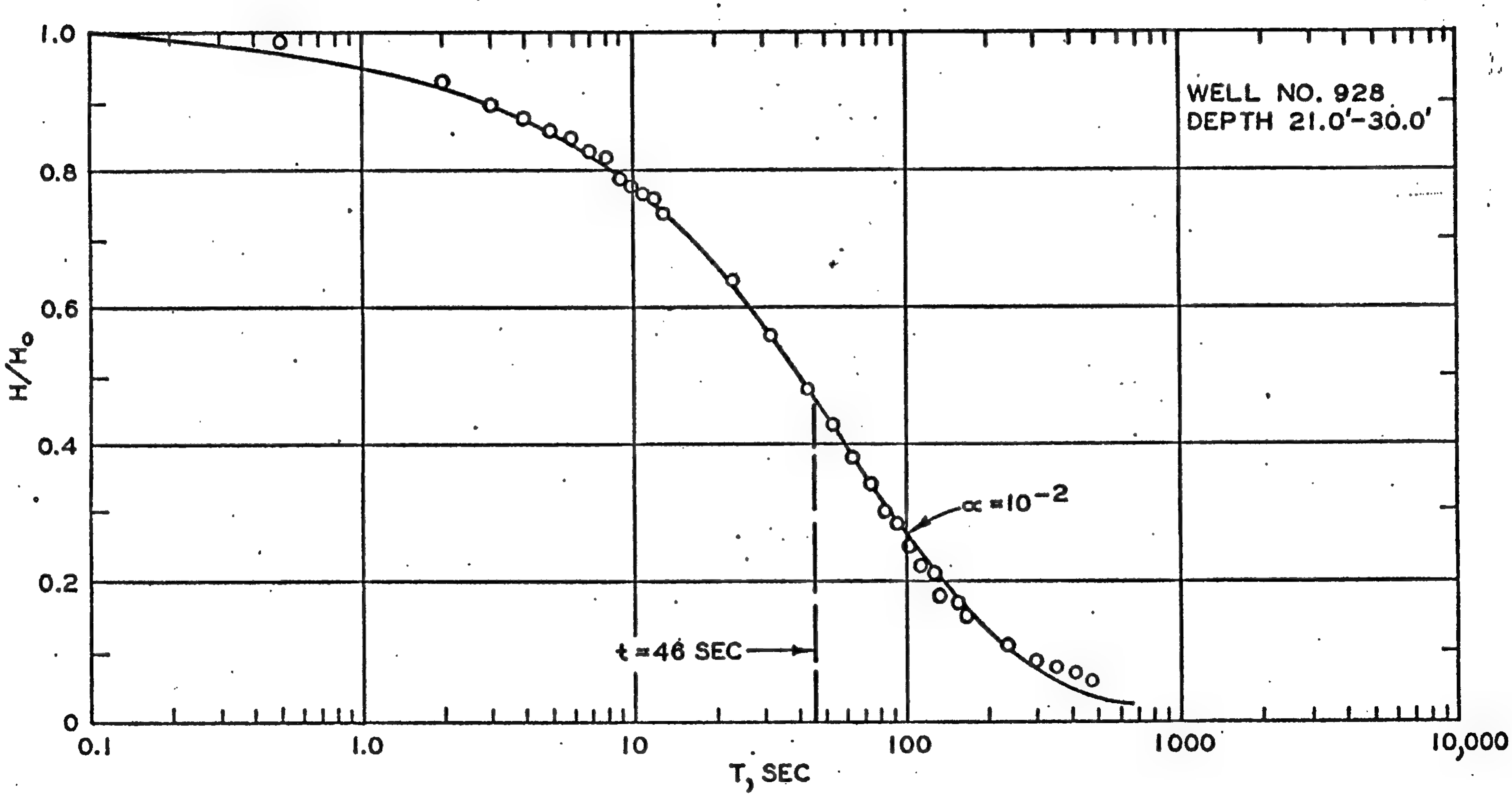
Field Permeability Test Data
with Type Curve

depth 2… 40.3

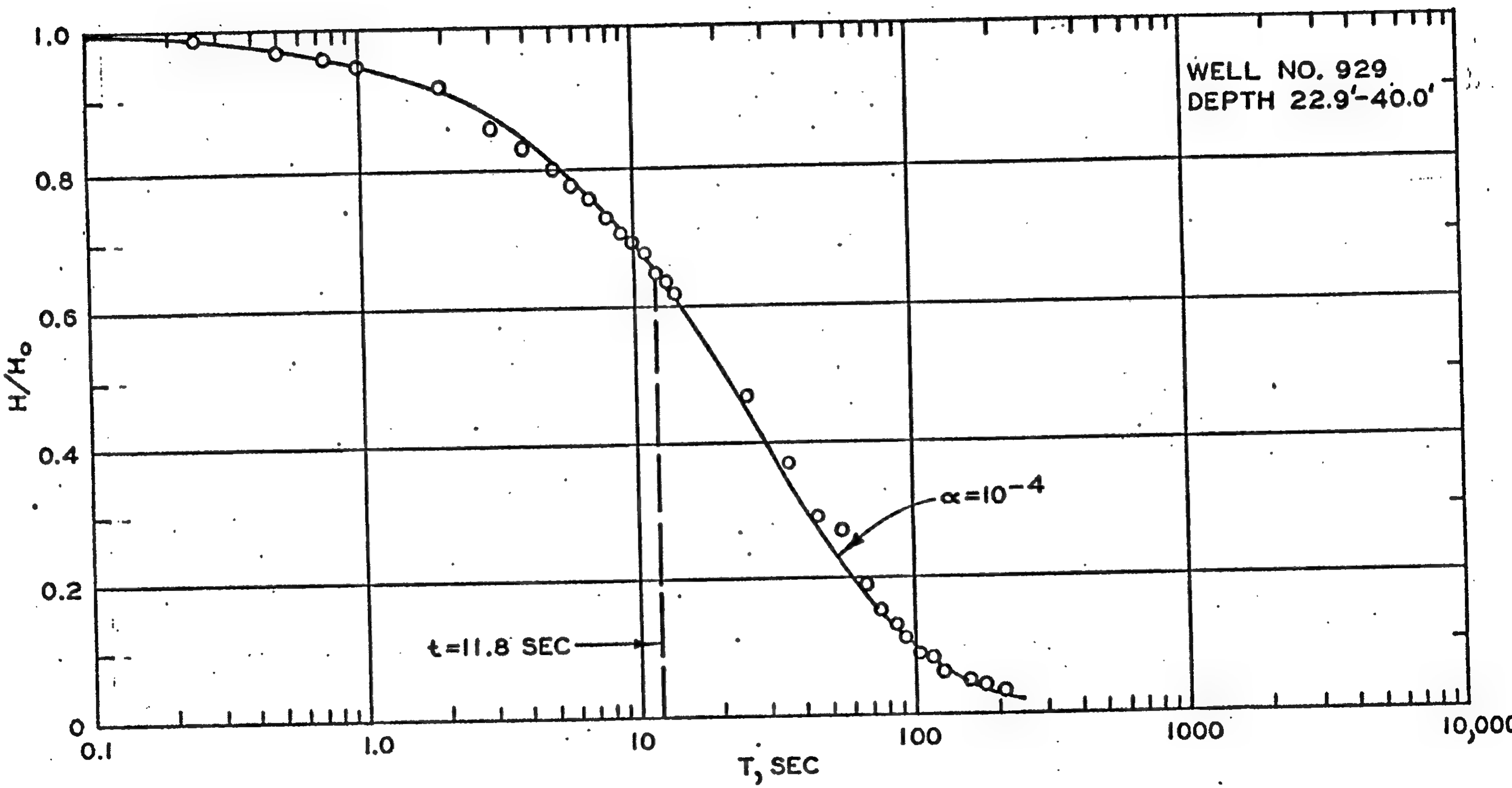


Field Permeability Test Data
with Type Curve

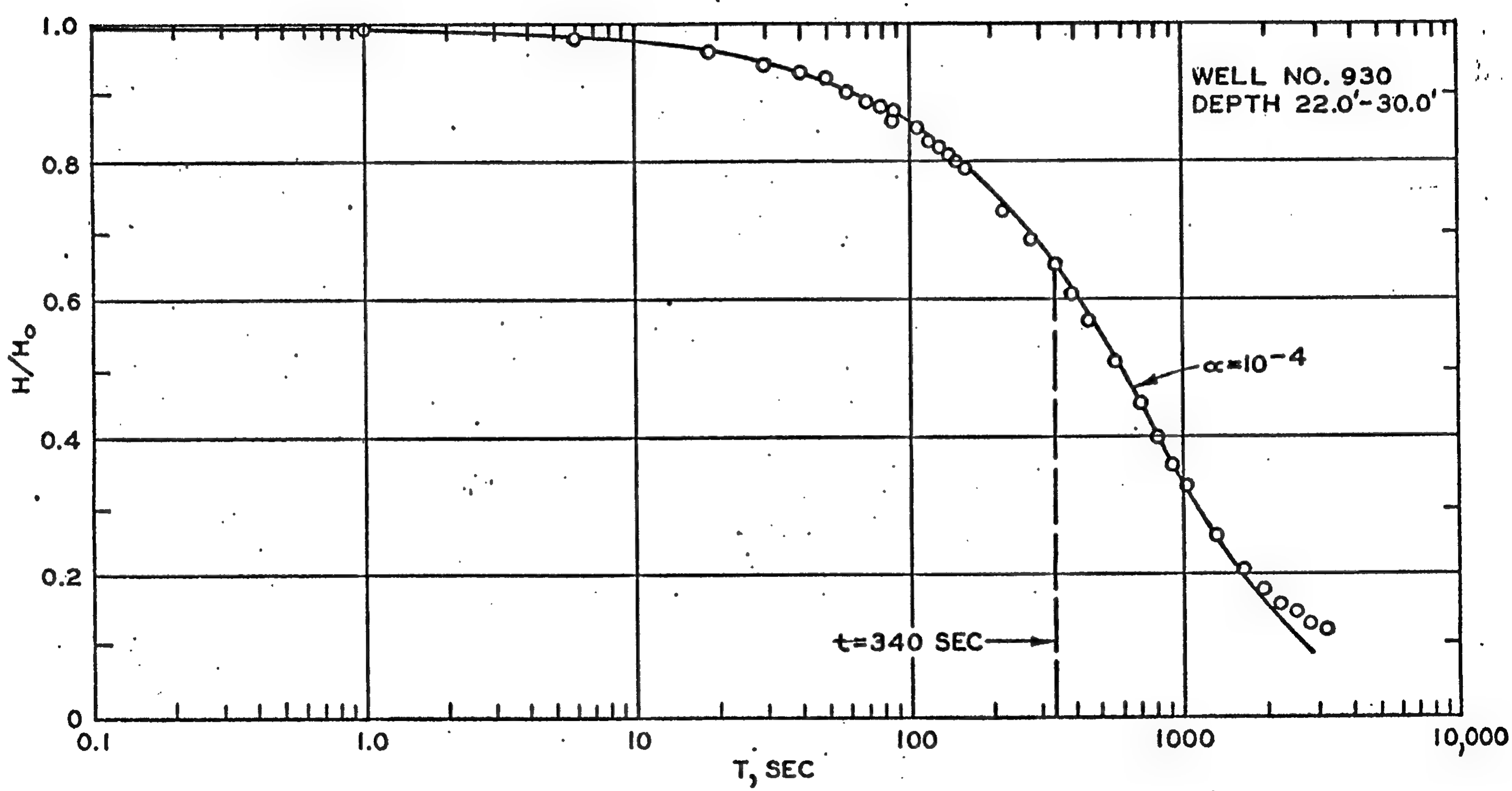
depth 21.0-30.0



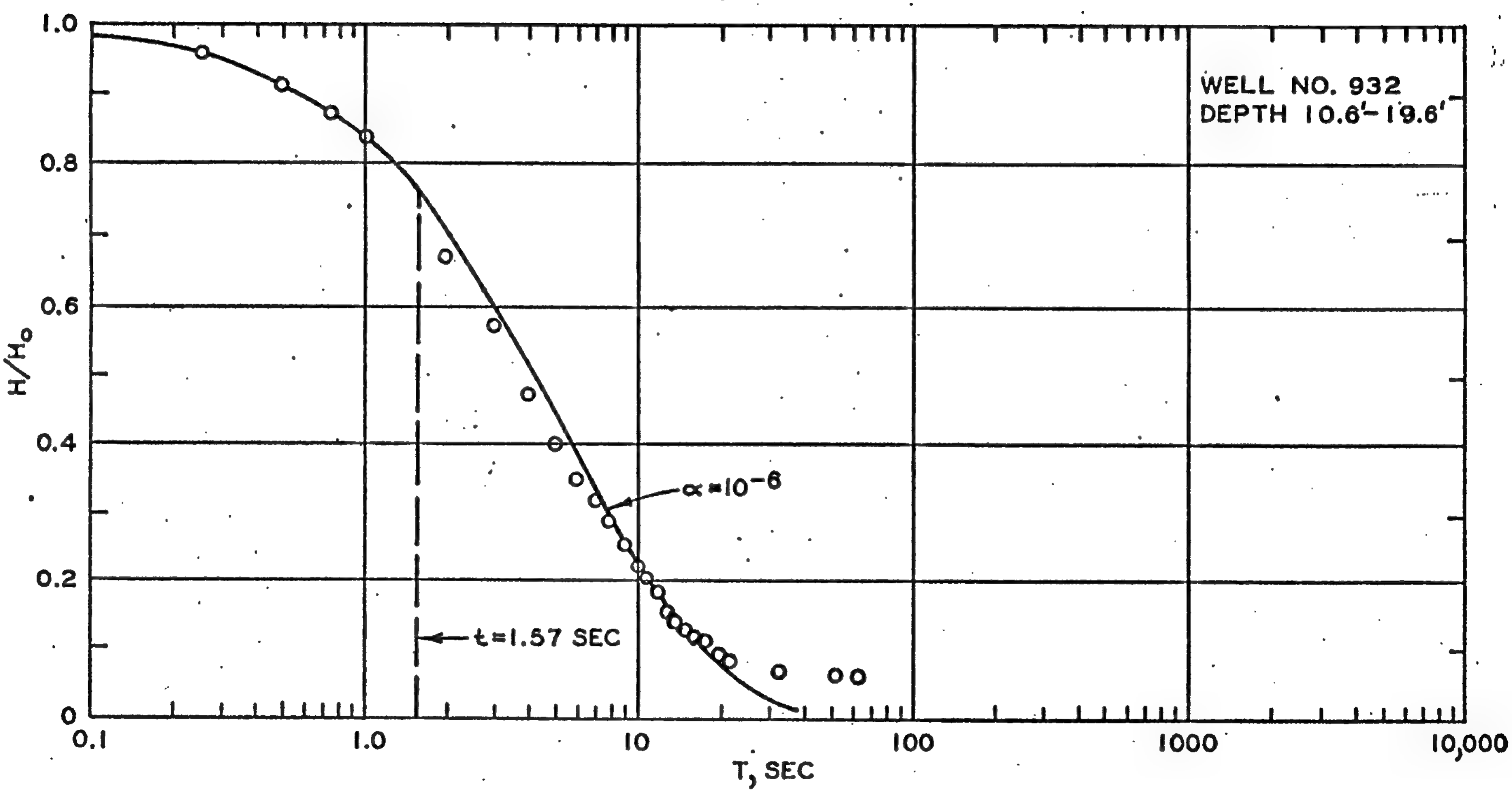
Field Permeability Test Data
with Type Curve



Field Permeability Test Data
with Type Curve

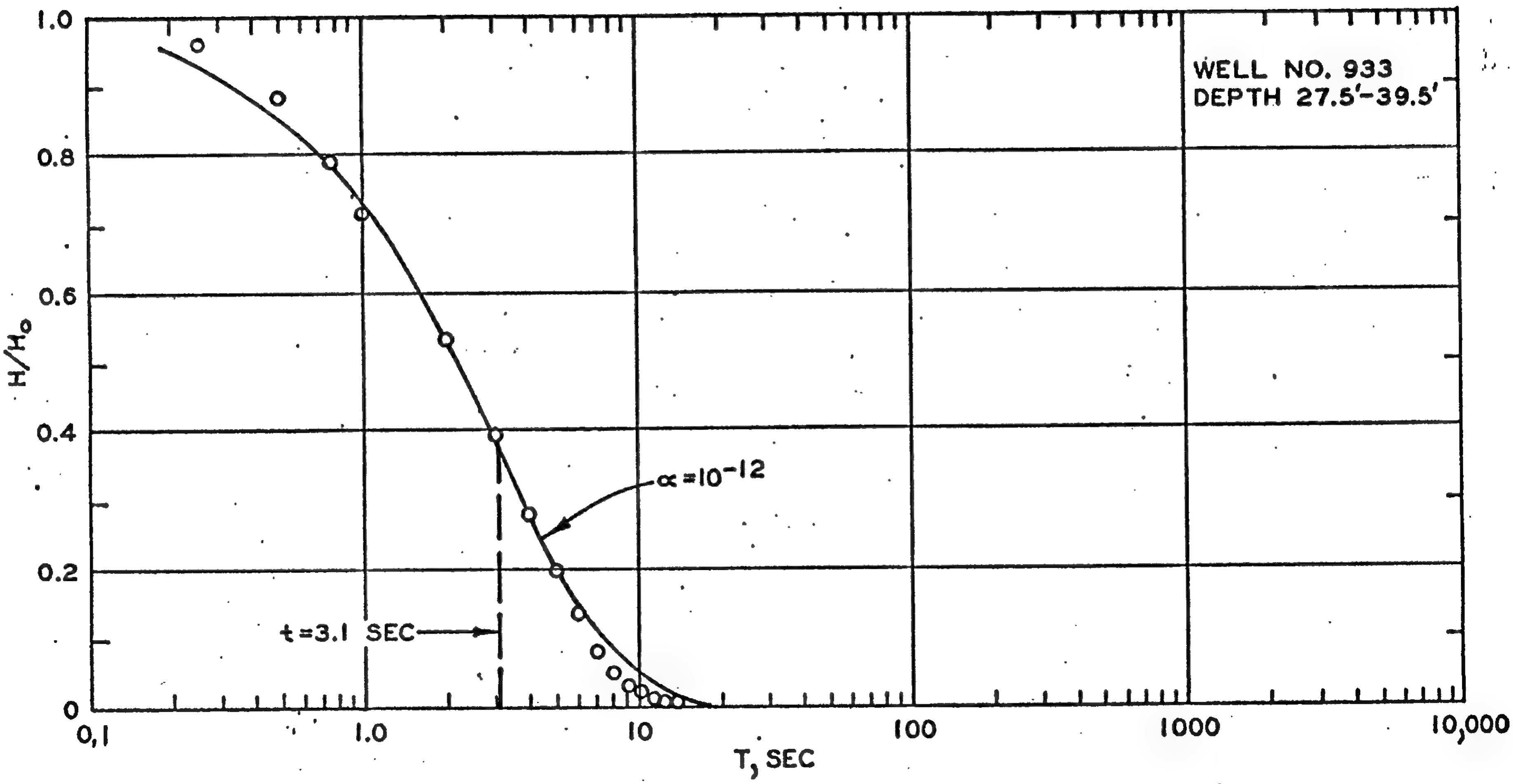


Field Permeability Test Data
with Type Curve



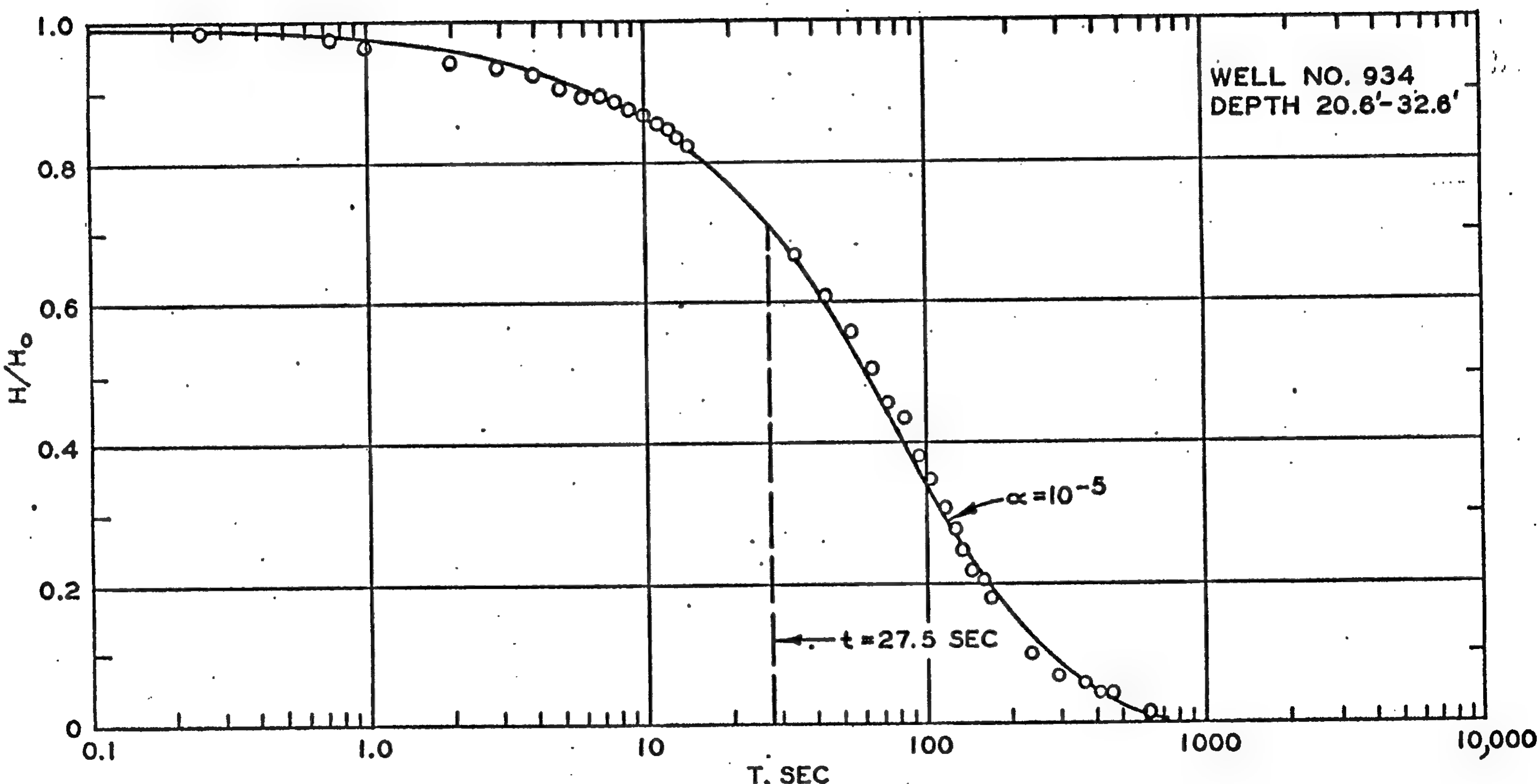
Field Permeability Test Data
with Type Curve

depth 27.5-



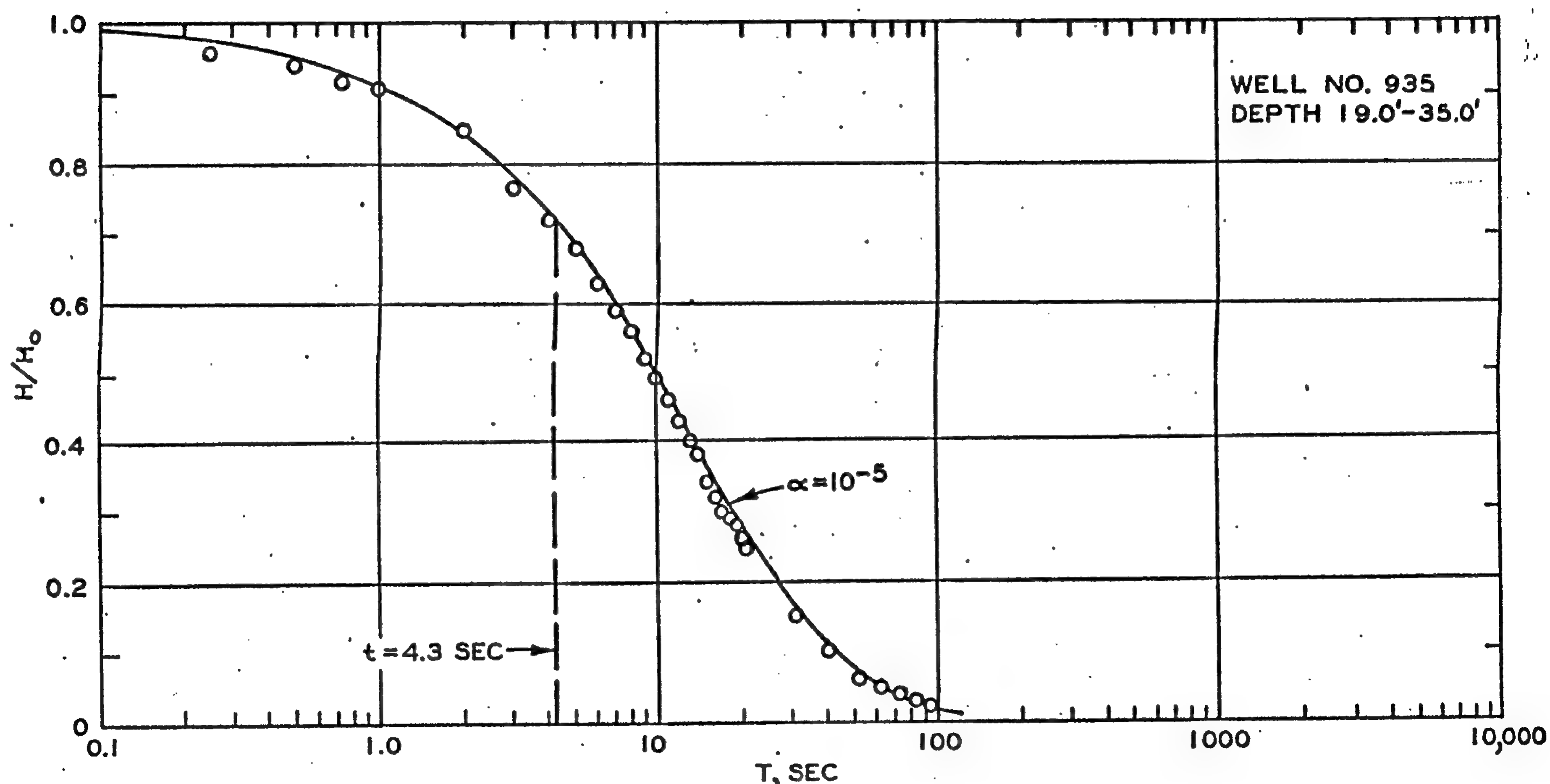
Field Permeability Test Data
with Type Curve

depth 20.6-3?

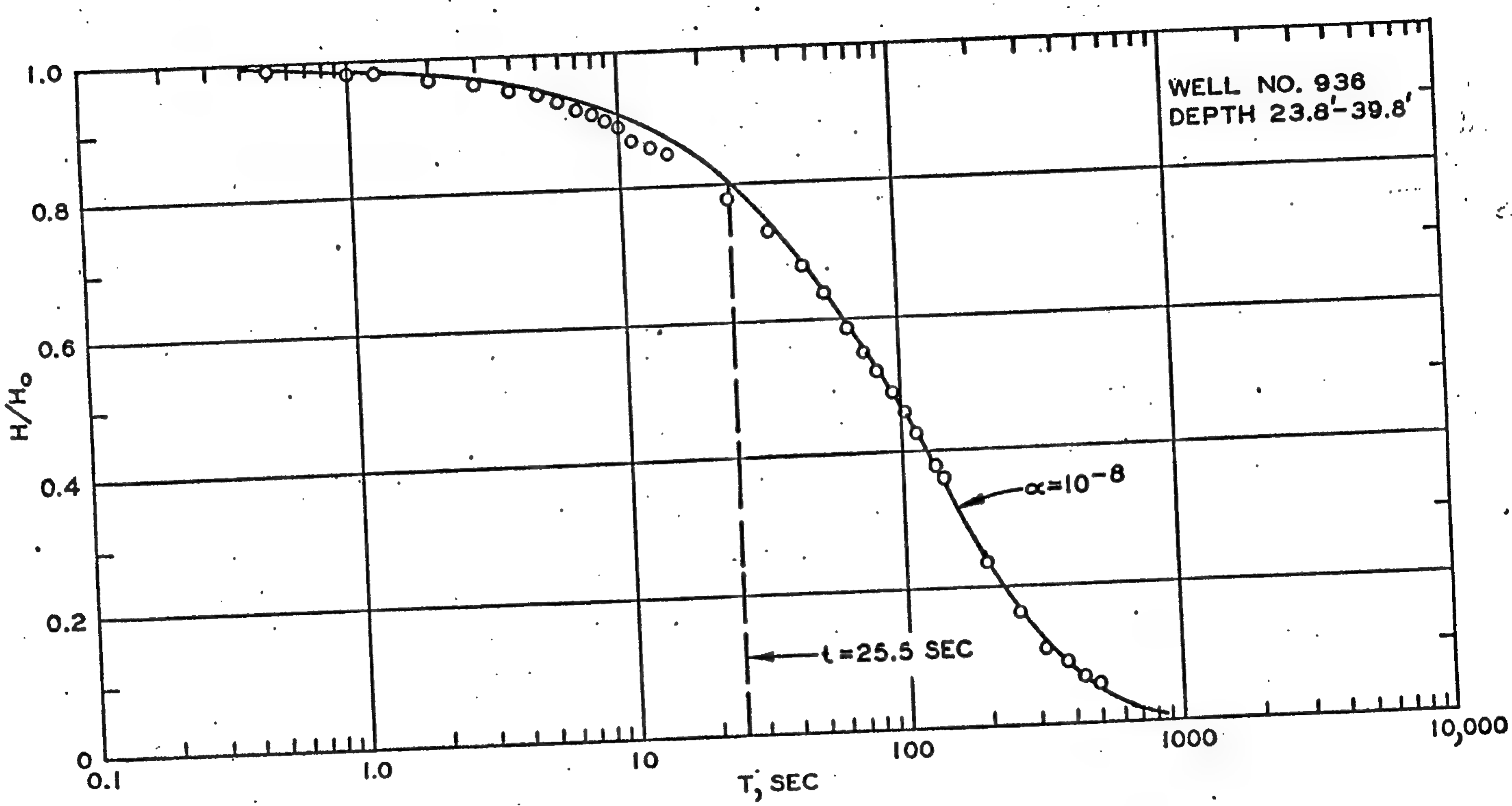


Field Permeability Test Data
with Type Curve

depth 19.0-35.0



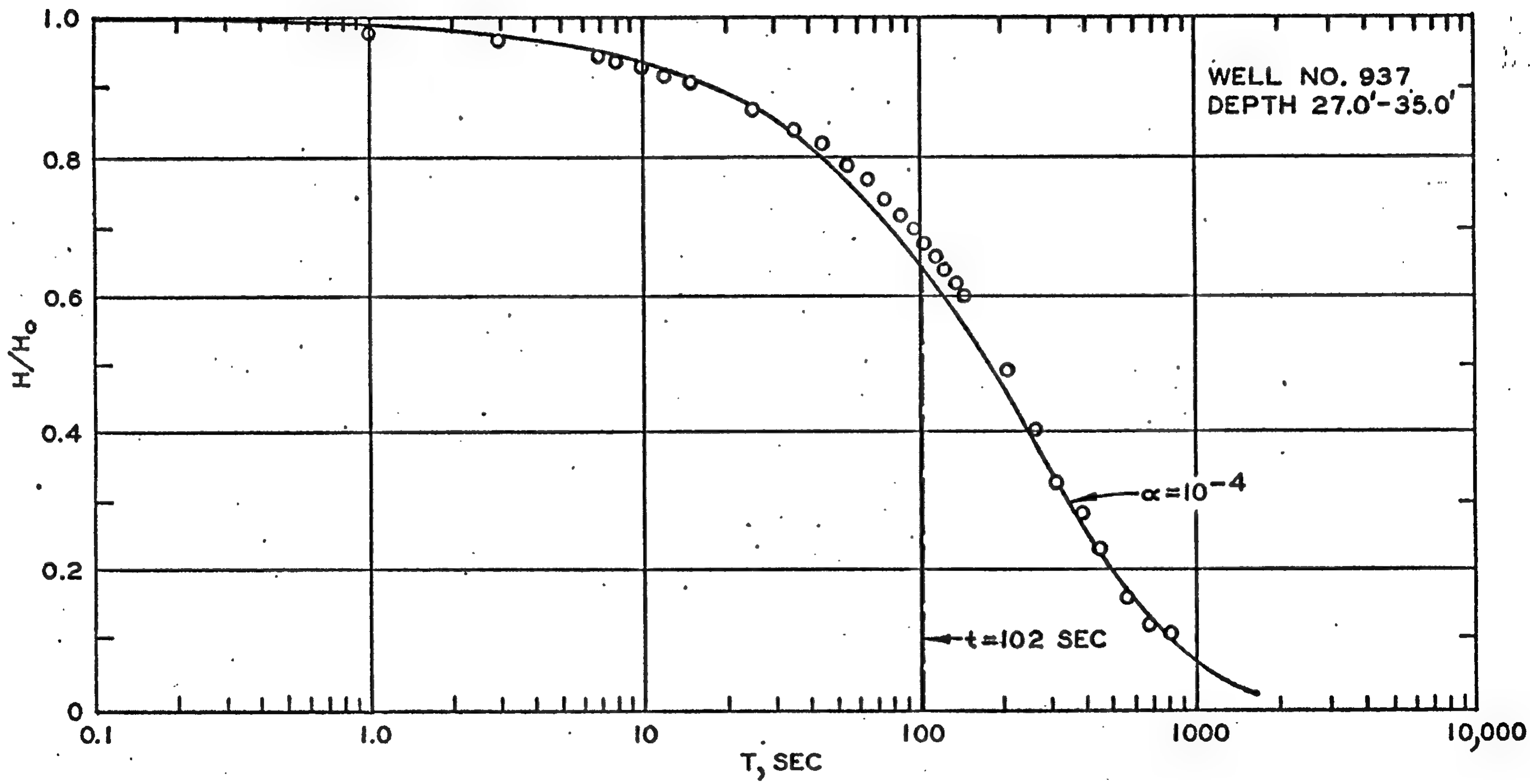
Field Permeability Test Data
with Type Curve



Field Permeability Test Data
with Type Curve

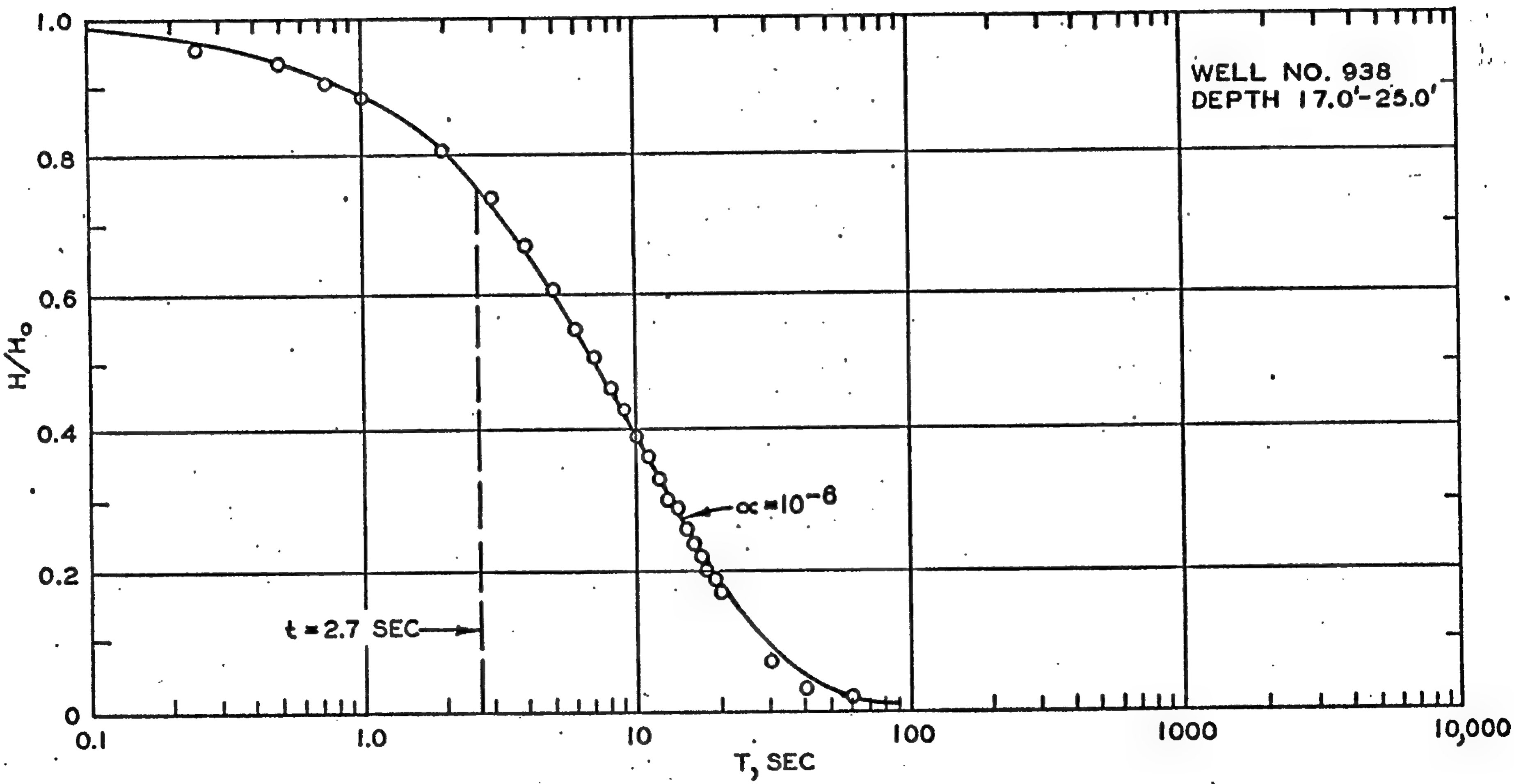
Depth 23.8-39.8

Well 937
Depth 27.0-35.0



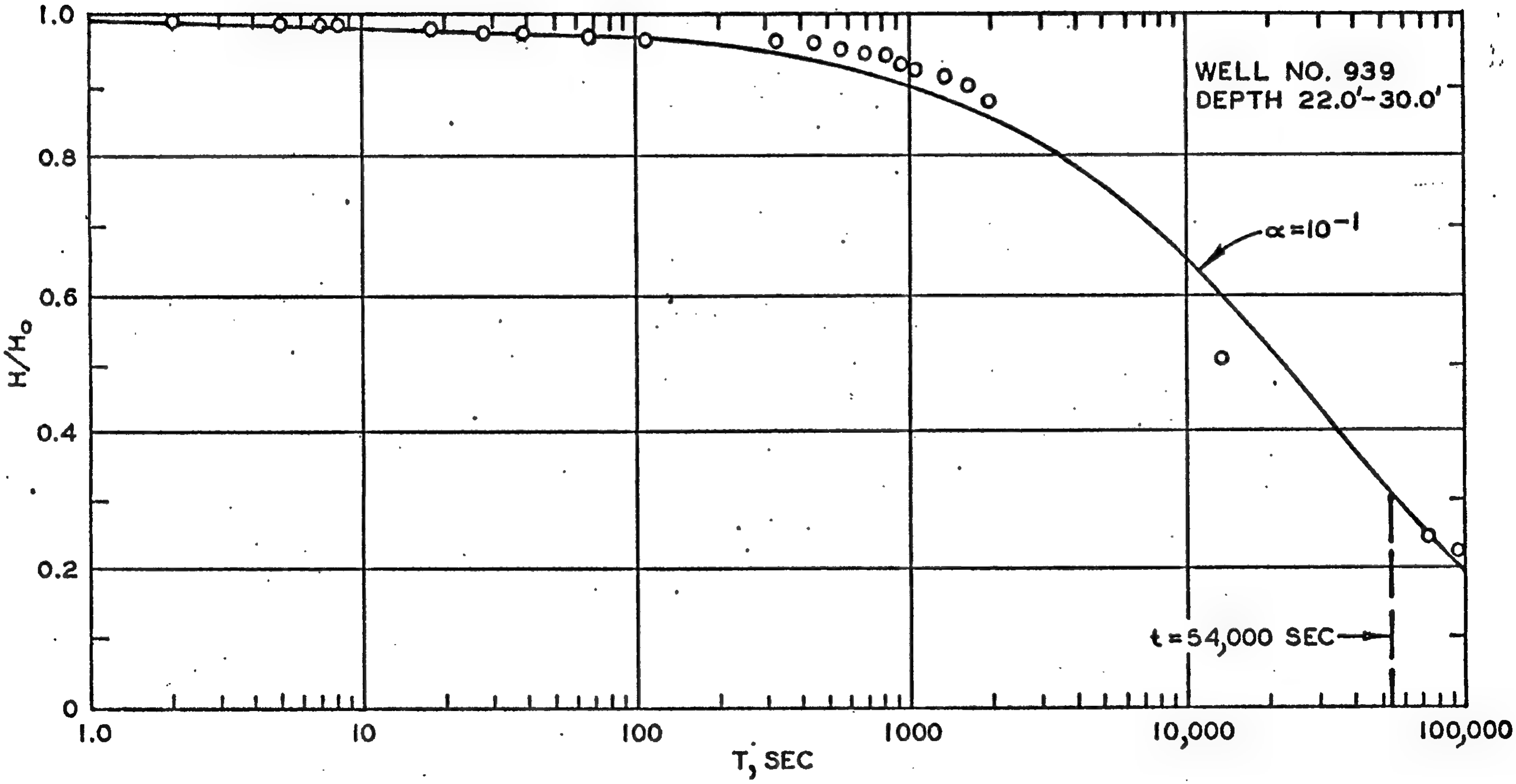
Field Permeability Test Data
with Type Curve

Depth 17.0-25.



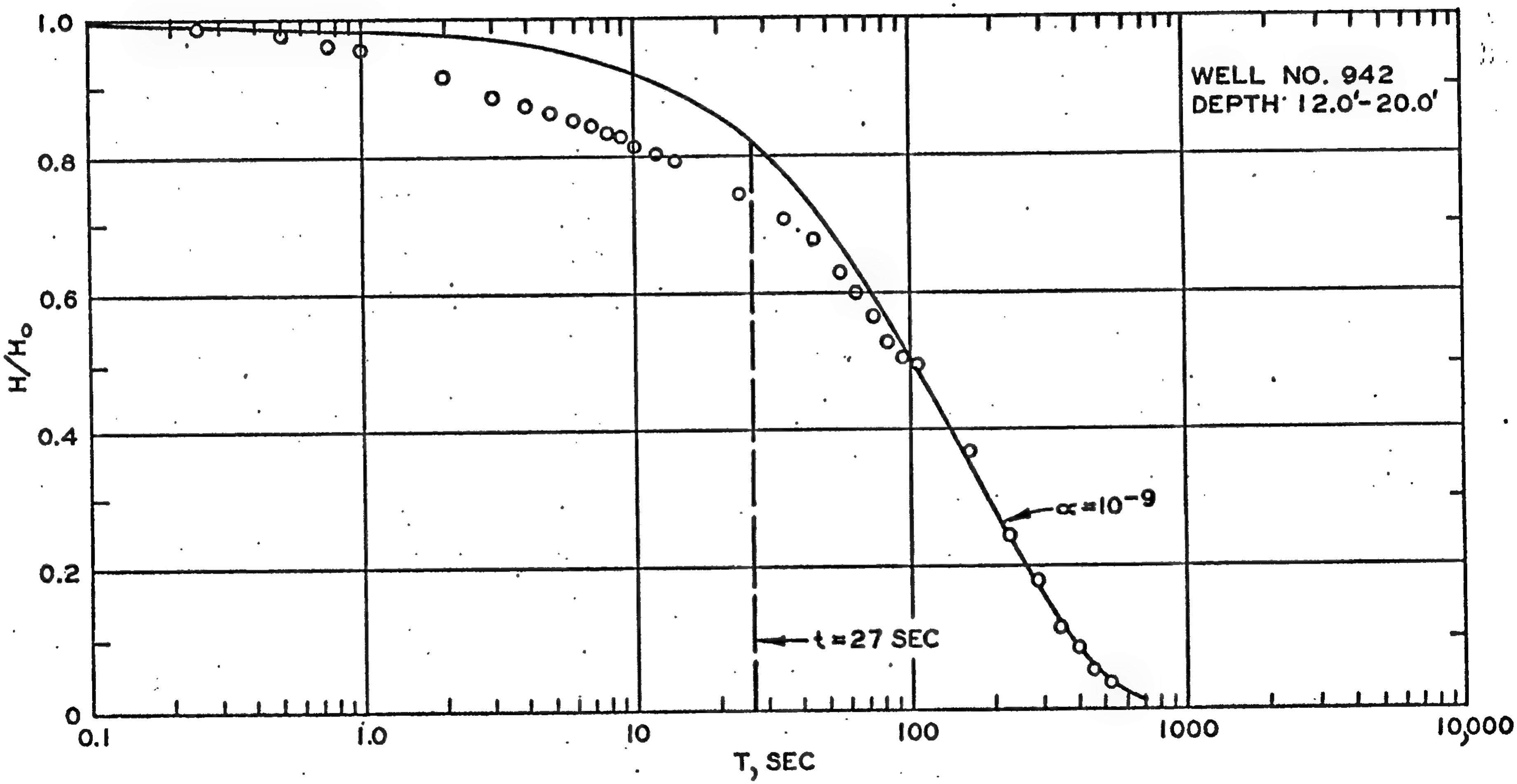
Field Permeability Test Data
with Type Curve

Dep. - 22.0 - 30.0



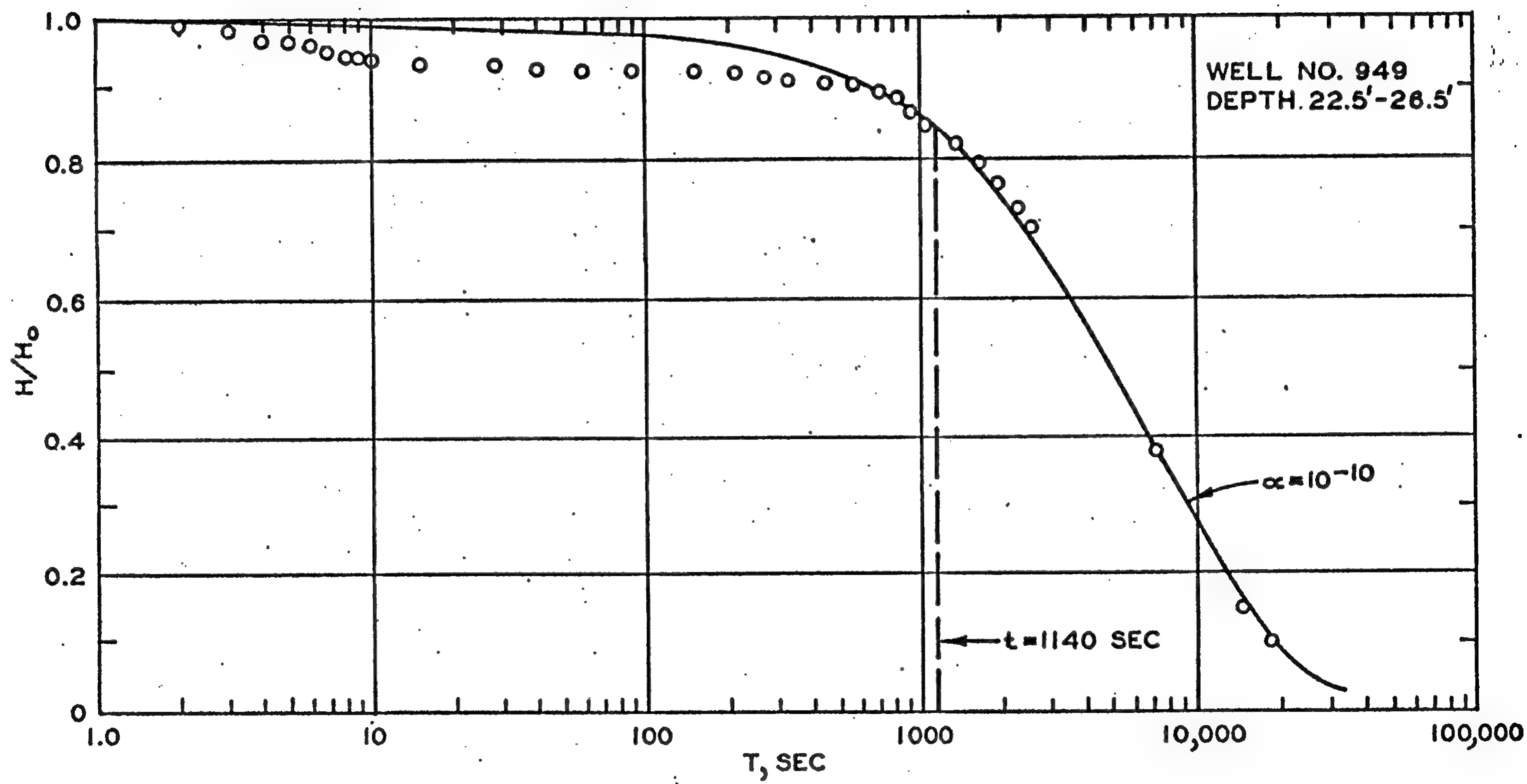
Field Permeability Test Data
with Type Curve

Depth 12.0-2[illegible]

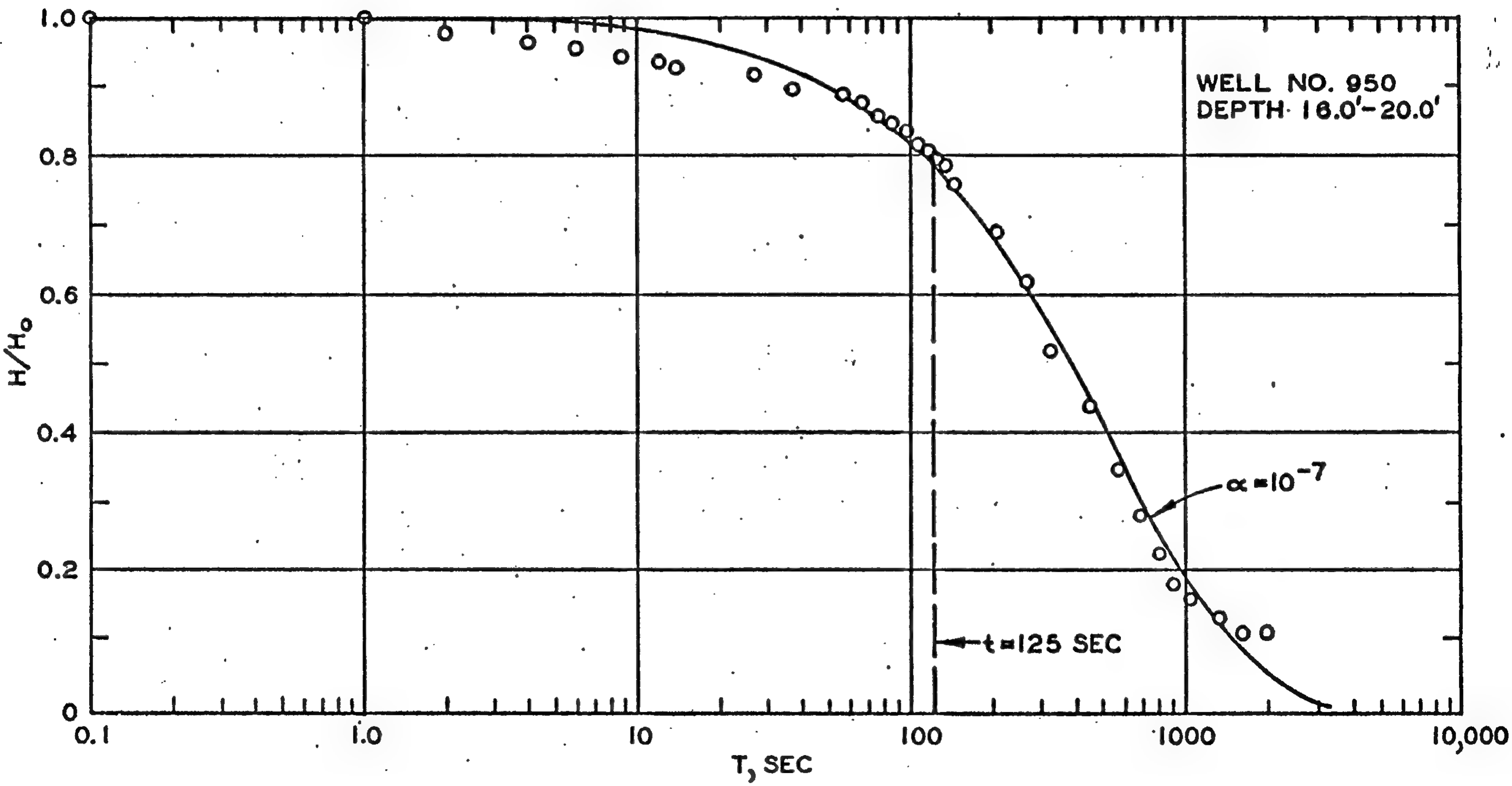


Field Permeability Test Data
with Type Curve

Depth 22.5-26..

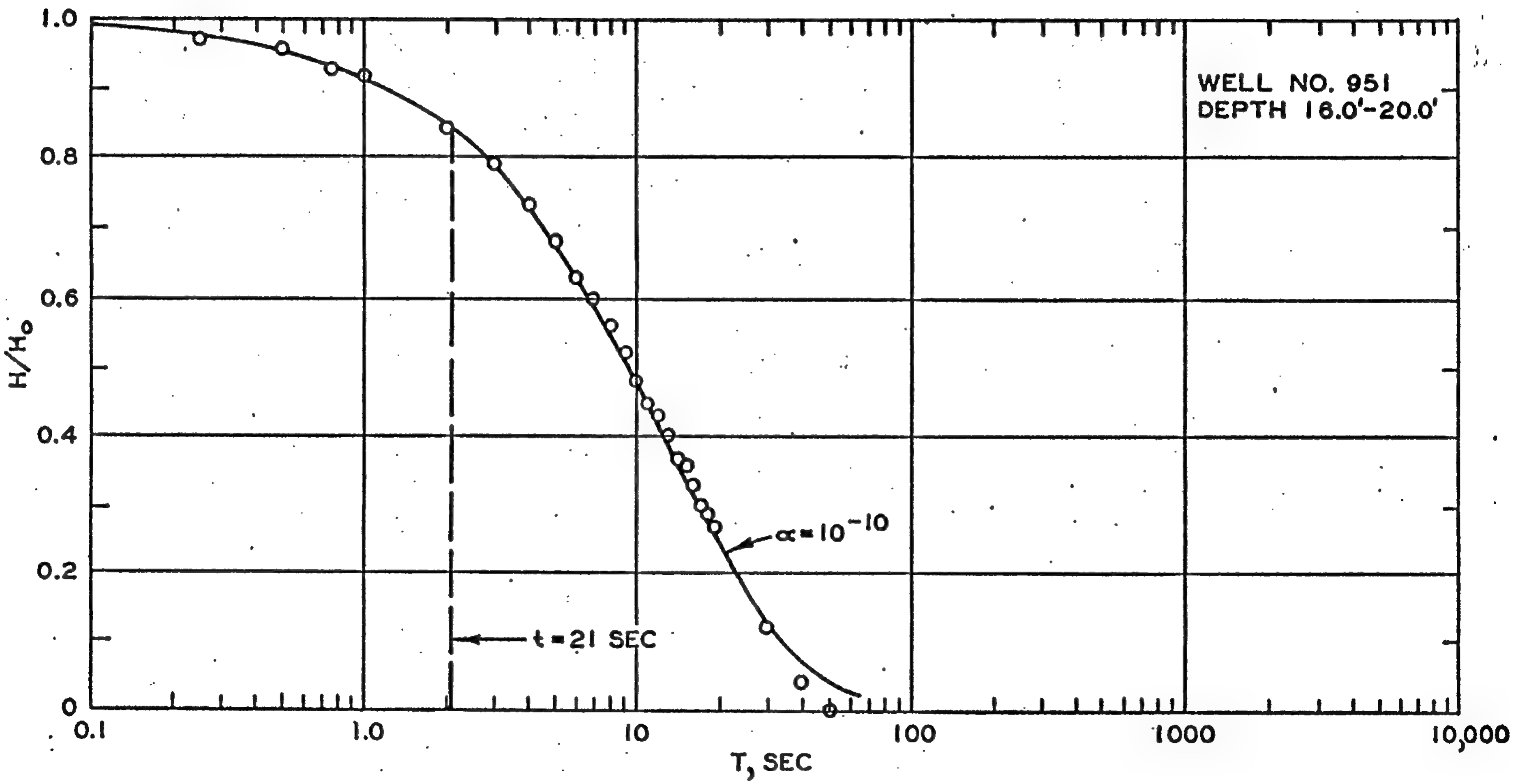


Field Permeability Test Data
with Type Curve



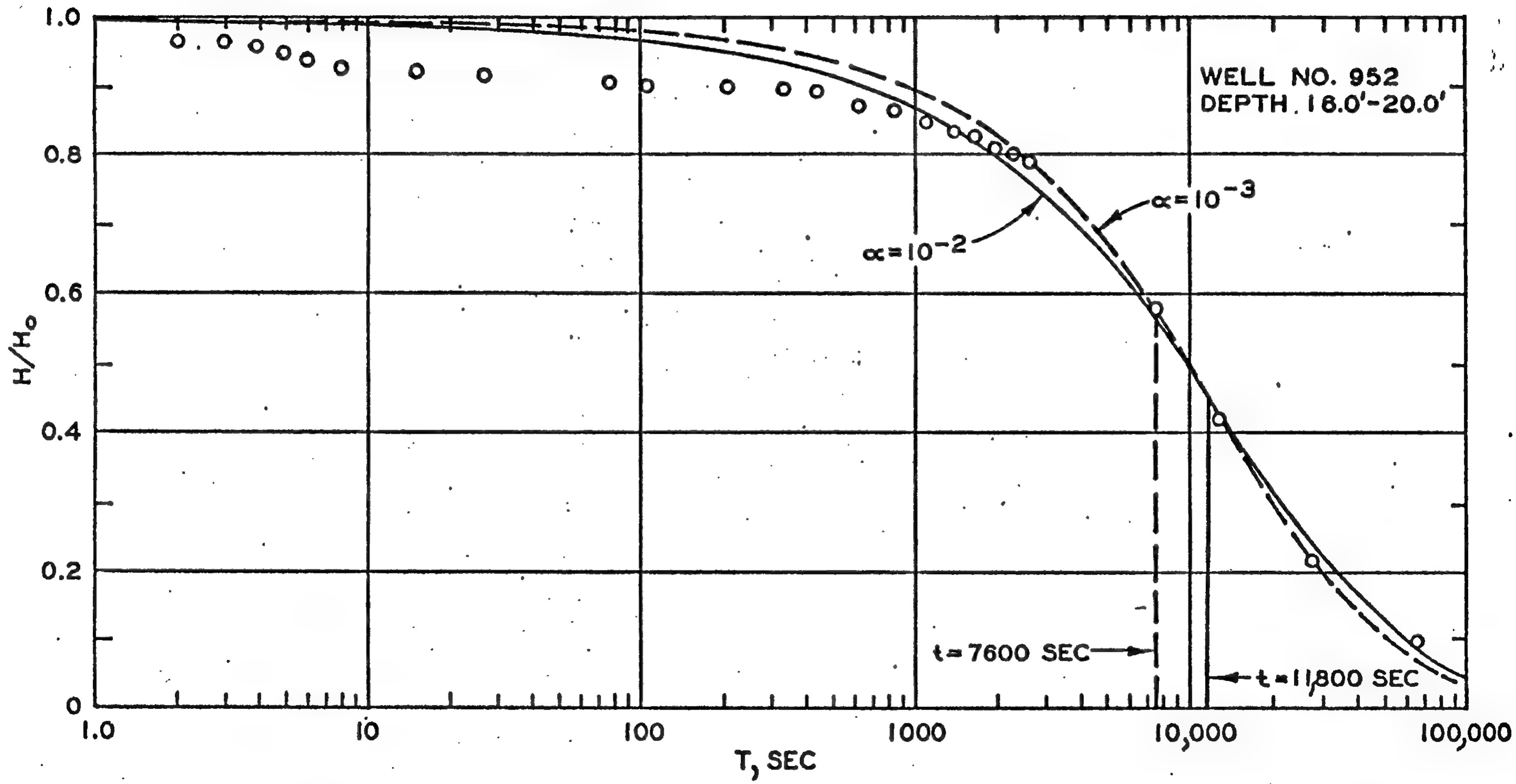
Field Permeability Test Data
with Type Curve

Depth 16.0-20.0



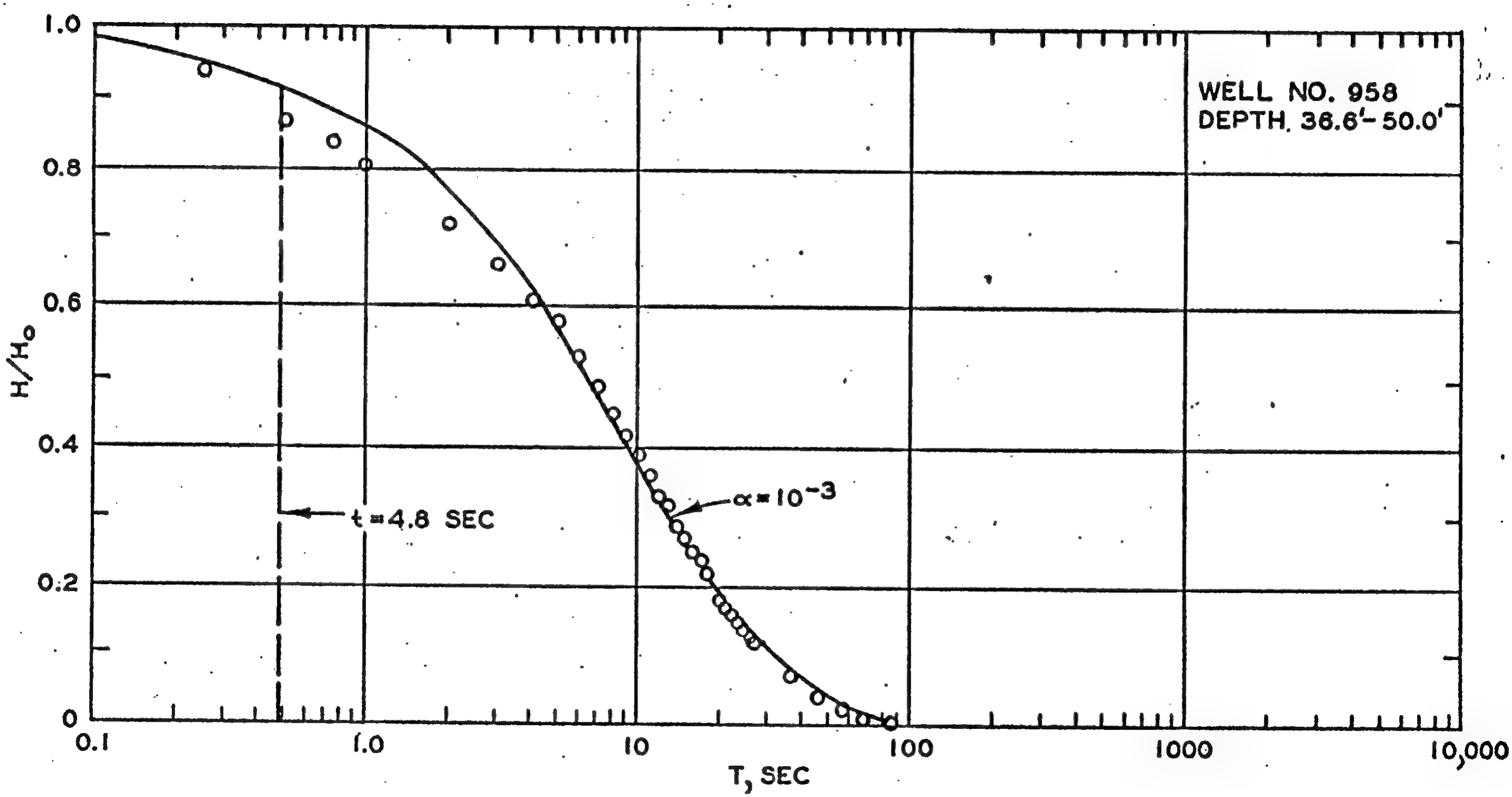
Field Permeability Test Data
with Type Curve

Depth 16.0



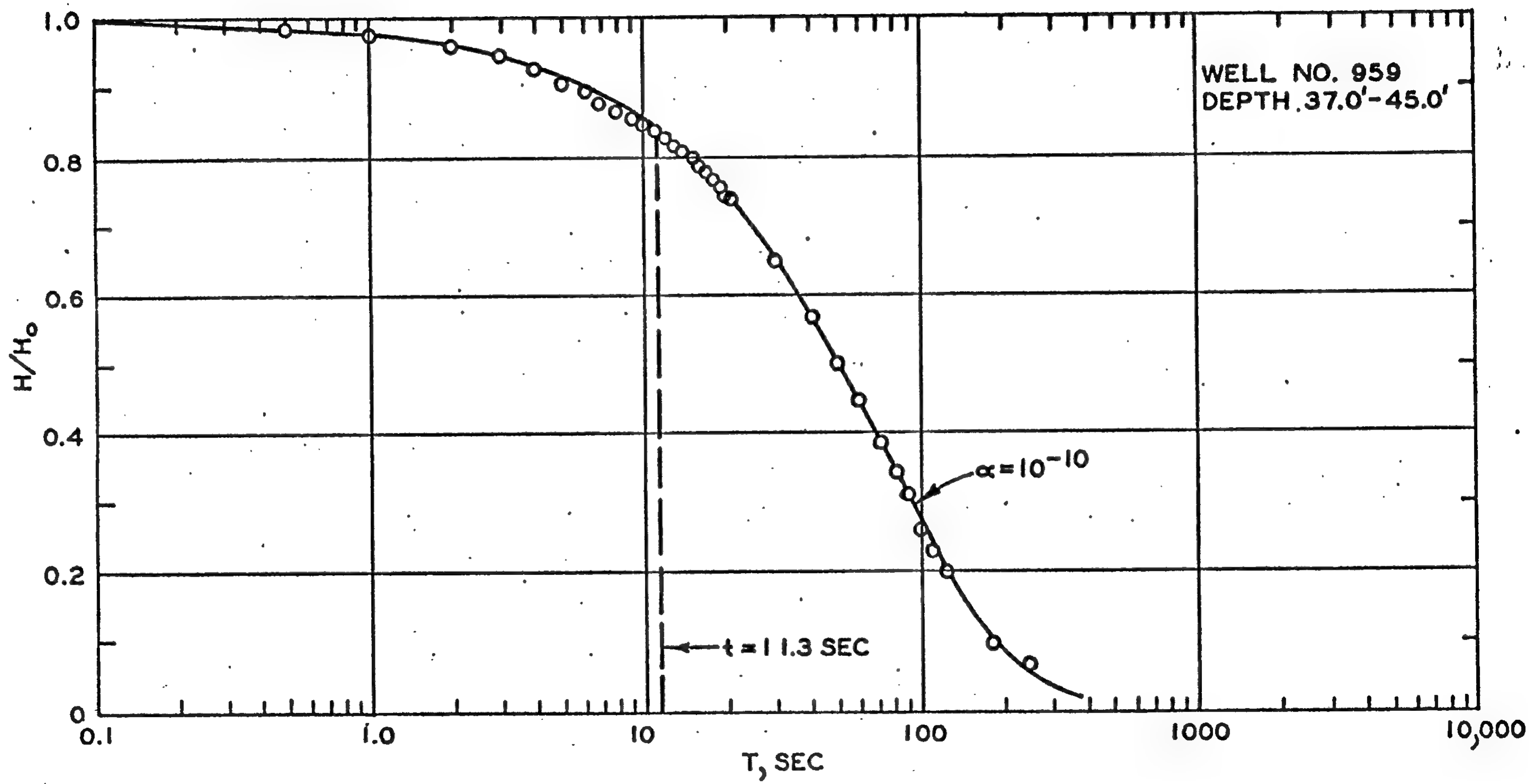
Field Permeability Test Data
with Type Curve

Depth 36.6-50.0'



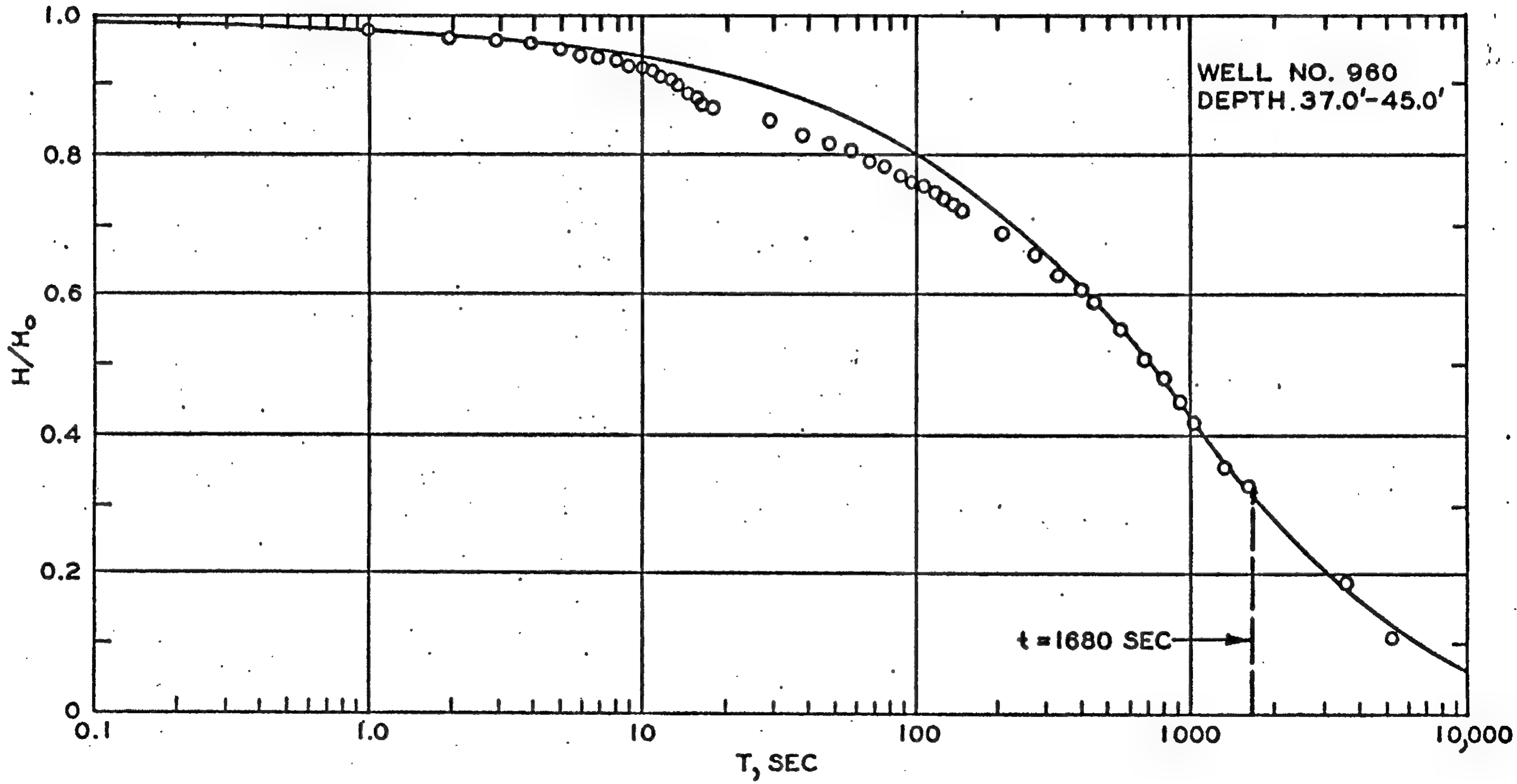
Field Permeability Test Data
with Type Curve

Depth 37.0-45.0



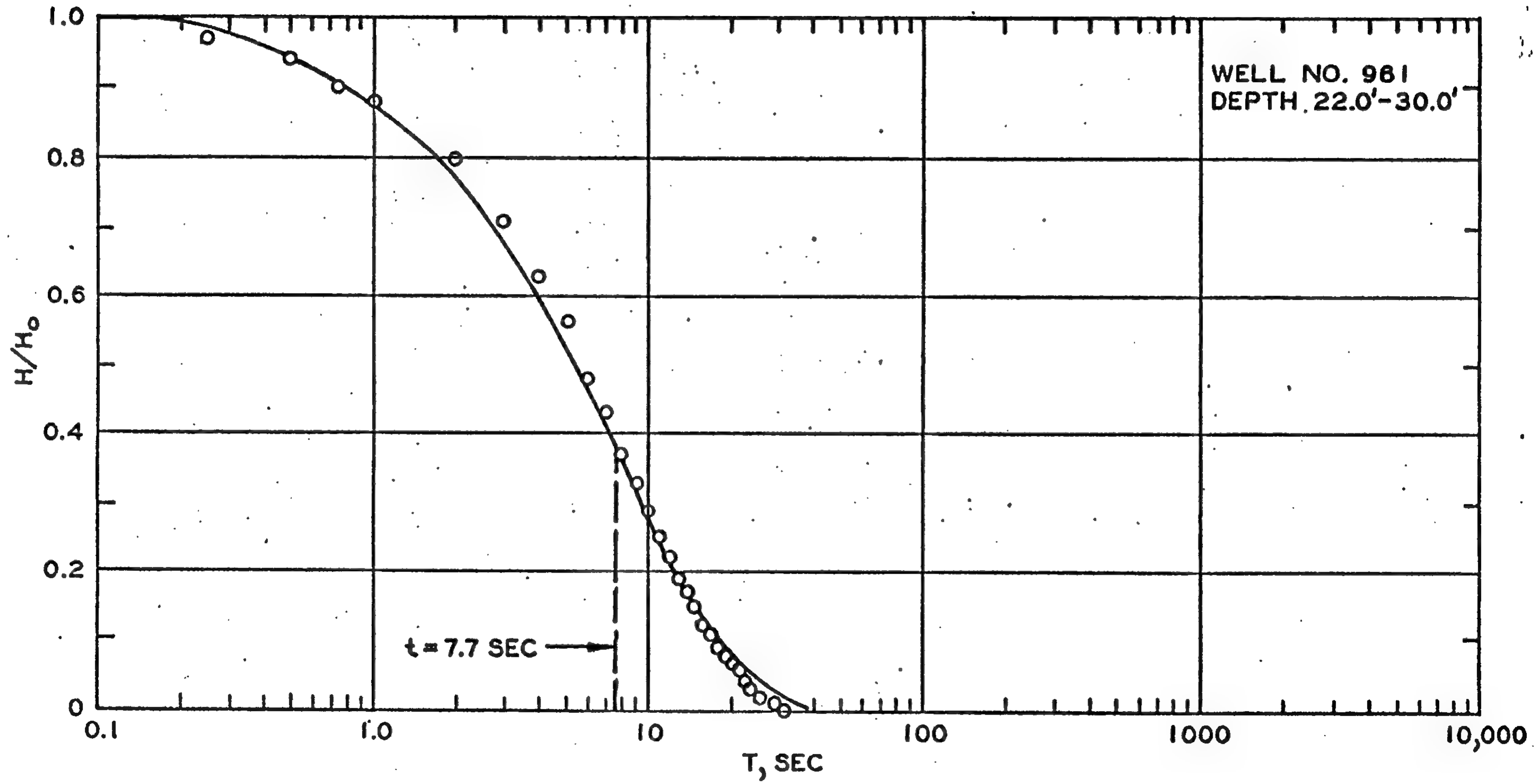
Field Permeability Test Data
with Type Curve

Well 960
Depth 37.0-45.0'



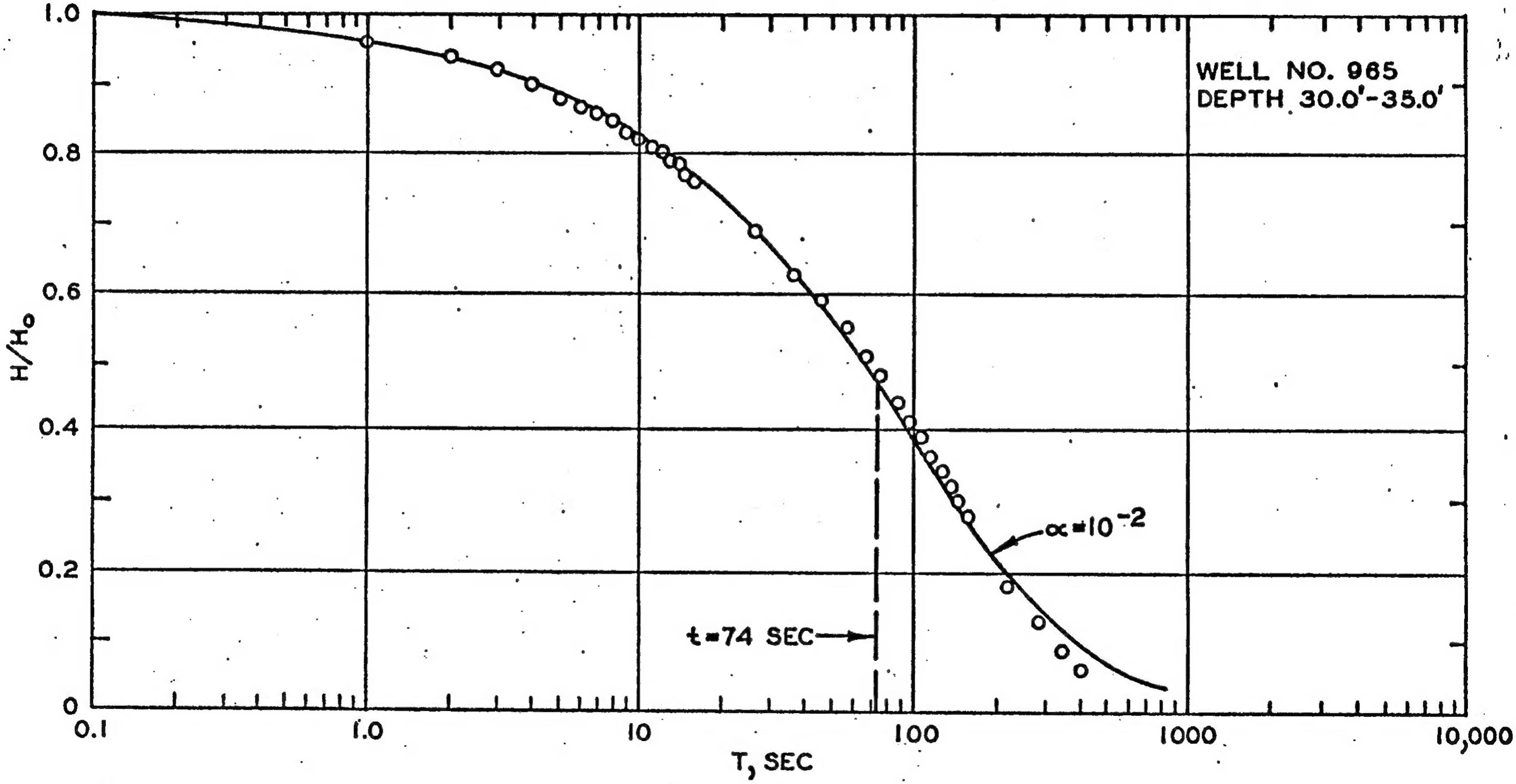
Field Permeability Test Data
with Type Curve

Well 961'
Depth 22.0-30.0



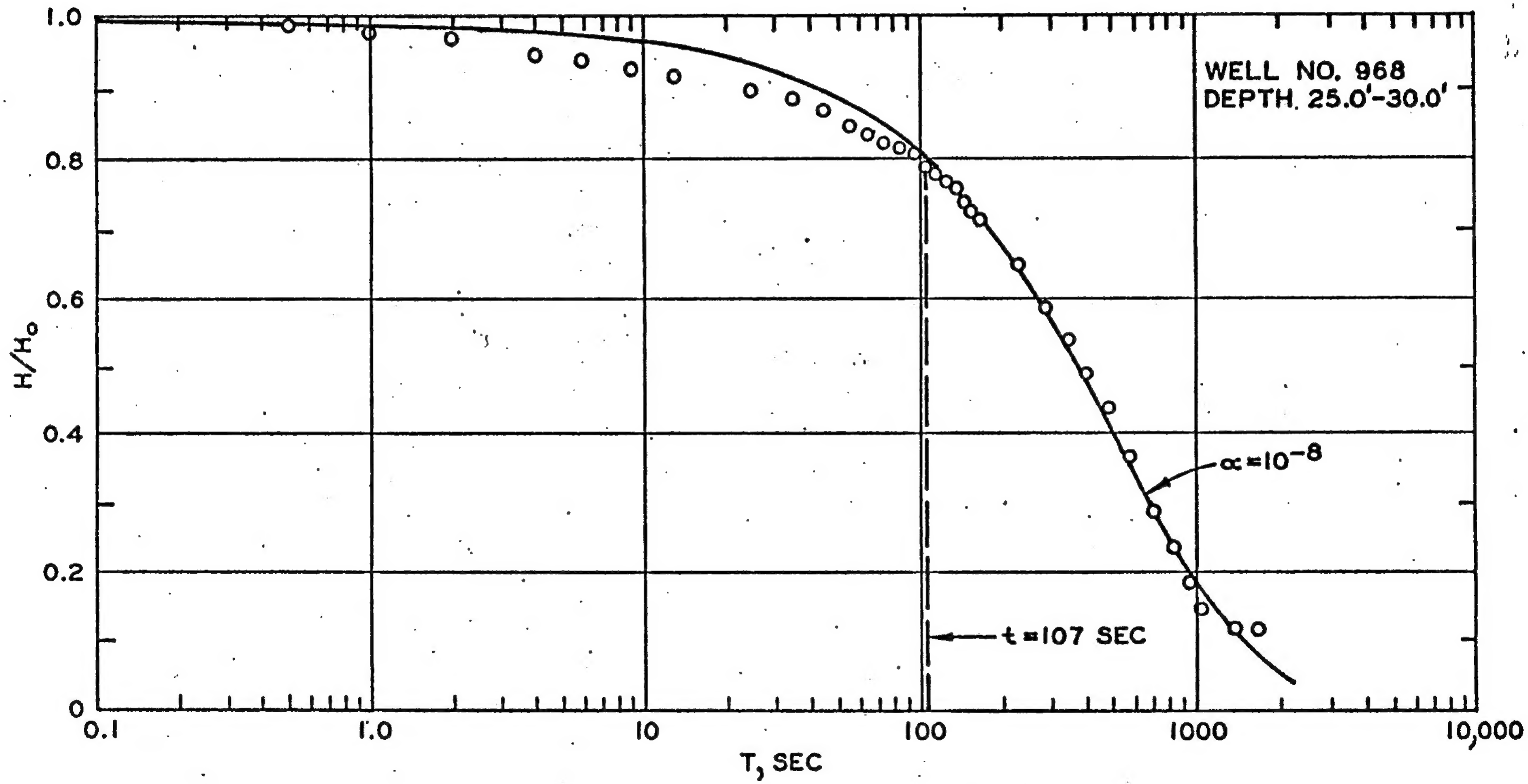
Field Permeability Test Data
with Type Curve

Well 965
Depth 30.0 - 35.0



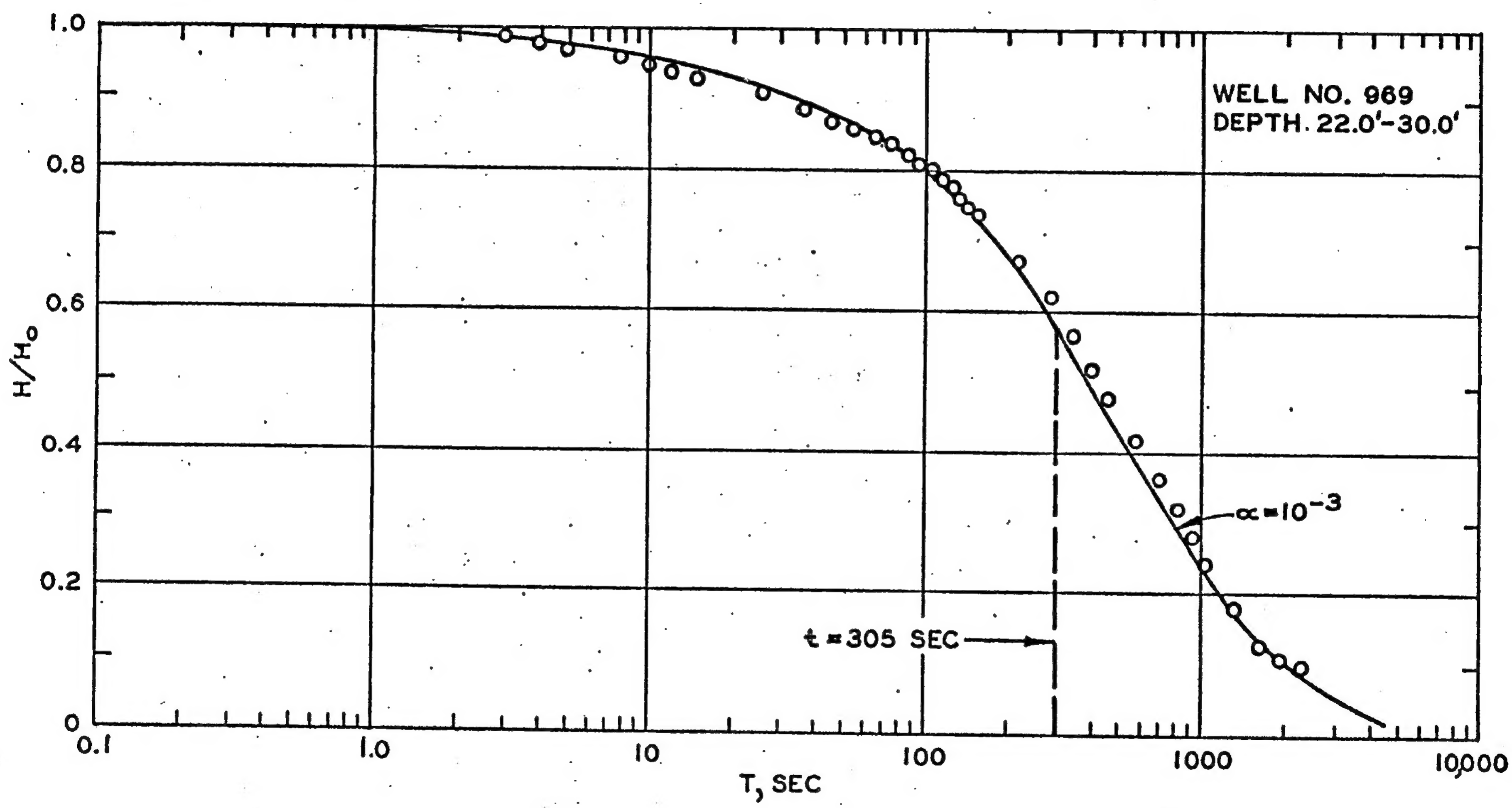
Field Permeability Test Data
with Type Curve

Well 968
Depth 25.0-30.0



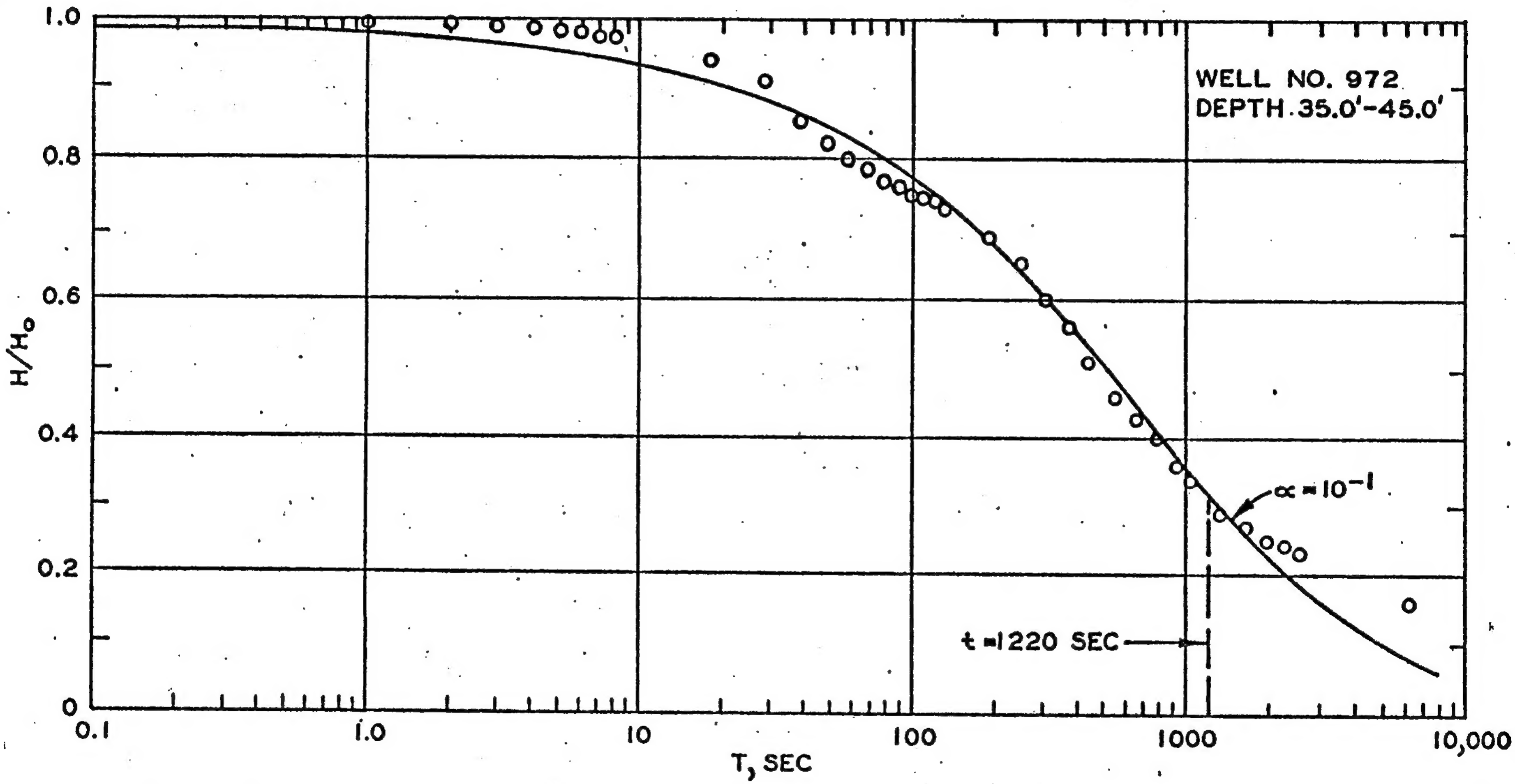
Field Permeability Test Data
with Type Curve

Well 969'
Depth 22.0-30.0



Field Permeability Test Data
with Type Curve

WELL 972
DEPTH 35.0-45.0



Field Permeability Test Data
with Type Curve